SUSTAINABLE TRANSITIONS IN ENERGY AND WATER SYSTEMS

A Dissertation
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Public Policy in the
School of Public Policy

Georgia Institute of Technology
December 2017

SUSTAINABLE TRANSITIONS IN ENERGY AND WATER SYSTEMS

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To every mother in science and to my children.

ACKNOWLEDGEMENTS

I would like to thank all of the professors and students at Georgia Tech that supported me in my pursuits. Dr. Thomas, thank you for guiding me through these years and being a role model for me. To Matt and Xiaojing, thank you for laughing and crying with me and teaching me so very much. To my wonderful husband, Misha you have made this entire venture possible- you are my co-author in life and I can never thank you enough for your endless support and sacrifice. To my beautiful and inspiring children- Elijah, Maksim, and Augustine- every ounce of this work is for you. I love you with all of my heart and you inspire me daily to make this world a better place. Finally, to God who has strengthened me and sharpened me in this season of study and sacrifice. I pray I can put all this work to good use.

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LIST OF SYMBOLS AND ABBREVIATIONS

AAA	Atlanta Apartment Association
ACF	Apalachicola-Chattahoochee-Flint
ACFS	Apalachicola-Chattahoochee-Flint Stakeholders
ACT	Alabama-Coosa-Tallapoosa River Basin
AP2	Air Pollution Emission Experiments and Policy Model
ASI	Advanced Solar Initiative
BOMA	Building Owners Management Association
BTM	Behind-the-Meter
CEP	City Energy Project
CBR	Commercial Board of Realtors
CPR	Common-Cool Resources
CO2	Carbon
Corps	U.S. Army Corps of Engineers
DERs	Distributed Energy Resources
DGPV	Distributed Solar Photovoltaics
ELCC	Effective Load Carrying Capacity
EDO	Exceptional Drought Operations
EPD	Environmental Protection Division
NPS	Federal National Pollutant Discharge
GHG	Green House Gas
GIS	Geographic Information System
GPAT	Georgia Policy Analysis Tool
GPC	Georgia Power Company

GT-DSM	Georgia Tech Demand Side Management
HB 237	Comprehensive Statewide Water Management Planning Act
IOUs	Investor-Owned Utilities
IMT	Institute Market for Transformation
IUWM	Integrated Urban Water Management
kWh	Kilowatt Hour
LCOE	Levelized Cost of Energy
LID	Low-Impact Development
MLP	Multi-Level Perspective
MW	Megawatt
MWh	Megawatt Hour
Mgals	Million Gallons
NEM	Net Metering
NH3	Ammonia
NOAA	National Oceanic and Atmospheric Academy
NOx	Nitrogen Oxide
NRDC	Natural Resource Defense Council
NREL	National Renewable Energy Laboratory
NGCTs	Natural Gas Combustion Turbines
O&M	Operations and Maintenance
PACE	Property Assessed Clean Energy
PM2.5	Fine Particulate
PM10	Particulate Matter
PPA	Power Purchase Agreements

PUC	Public Utilities Commission
RWH	Rainwater Harvesting
RPS	Renewable Portfolio Standard
RNR	Renewable & Non-Renewable Tariff
REC	Renewable Energy Credit
SCC	Social Cost of Carbon
SEPAS	Solar Energy Procurement Agreements
SEPA	Southeast Power Administration
SO2	Sulfur Dioxide
SP	Solar Purchase Tariffs
SWMP	Statewide Management Plan
T&D	Transmission and Distribution
VOC	Volatile Organic Compound
VOS	Value of Solar
VOST	Value of Solar Tariff
WQPA	Water Quality Protection Act of 1964

SUMMARY

The United States, and the world over, is amidst a major socio-technical transition of its energy and water systems. Environmental concerns, such as climate change and resource scarcity, present complex management and societal challenges. New technological innovations present opportunities for more efficient, economic, and equitable use of natural resources but will require substantial shifts in the policy processes, regulatory institutions, user behaviors, and the frameworks that govern resource use. Addressing these challenges can only be realized by deep structural changes in the behavior of energy and water systems and society (Van den Bergh and Bruinsma, 2008; Grin et al., 2011) as well as strategic analysis to support a path forward.

This dissertation is a compilation of five research projects into the dynamics of sustainable transitions in the Unites States' Energy and Water Systems. Throughout the dissertation, the Multi-Level Perspective Framework is applied, a heuristic developed from the sociotechnical transition literature to diagram the relationship between three primary levels of any transition - the niche, the regime, and the sociotechnical landscape While each project is distinct in nature, I utilize the policy science and engineering literatures of participatory democracy, policy entrepreneurs, and systems analysis throughout the dissertation. Combined, I evaluate the role of actors and policy institutions, including regulatory frameworks and legal structures. I also develop new analytical models for valuing distributed resources.

CHAPTER 1. INTRODUCTION

This introduction section provides an overview of the theoretical framework that guides my dissertation, identifies the key analytical themes of each section, and provides an outline of each research project as well as defense for the methods chosen. Mine is a non-traditional dissertation and is a collection of five research projects all dedicated to examining the dynamics of sustainable transitions in water and energy systems.

The United States, and the world over, is amidst a major socio-technical transition of its energy and water systems. Environmental concerns, such as climate change and resource scarcity, present complex management and societal challenges. New technological innovations present opportunities for more efficient, economic, and equitable use of natural resources but will require substantial shifts in user behavior as well as the regulatory processes and frameworks that govern resource use. Addressing these challenges can only be realized by deep structural changes in the behavior of energy and water systems and society (Van den Bergh and Bruinsma, 2008; Grin et al., 2011).

Such systemic changes are often called 'socio-technical transitions', because they involve alterations and reconfigurations of the technologies, policies, markets, actors, infrastructure, and the cultural meaning of a system to society (Elzen et al., 2004; Geels, 2014; Geels and Schot, 2007). Inherent in any socio-technical system transition is the recognition that the status quo state of an existing system is not desired wholly by all societal actors. In contrast to the study of technology innovation driven simply by economic growth issues, the broad focus of the socio-technical transition literature is on understanding how surrounding and supporting societal constructs evolve and innovate to facilitate systematic change (Kemp et al. 1998). Under this conceptualization, a system innovation can be understood as a change from one socio-technical system to another.

Within the socio-technical transition literature, sustainable transition studies focus on analyzing how the socio-technical innovations, that are necessary for the creation of new, more sustainable trajectories, evolve from interacting cultural, technological, behavioral, economic, and institutional developments (Geels and Schot, 2007; Elzen, et al,2004; Grin, Rotmans, & Schot, 2010; Loorbach, 2007;). According to Elzen, et al, there are three primary aspects of any sustainable transition. One is the *technological substitution*, which is comprised of three sub-process:

(i) emergence of new technologies,
(ii) diffusion of new technologies, and
(iii) replacement of old technology by new technology.

The second aspect of the innovation is a *coevolution*, which includes changes in elements such as user practices, regulation, policy, actors, infrastructure, and cultural meaning. The final aspect of a system innovation is the emergence of new functionalities, which result in radical and new technical or behavioral capabilities as a result of the technological substitutions and coevolution innovations (Abernathy and Clark, 1985).

While each chapter in this dissertation is distinct, every work is situated in a broader field of understanding the dynamics of sustainable transitions in the energy and water system. I start this dissertation with the basic premise that the transformation of our water and energy systems towards a more sustainable state is not determined simply by any scientific or economic rationality, but rather there exists a wide range of social, political and institutional factors which interact to influence innovation. Specifically, the work presented in this dissertation is focused on understanding the innovation process of *coevolution* (Abernathy and Clark, 1985; Utterback, 1994) and how changes in regulation, the emergence of new actors, and new policy instruments are shaping a sustainable transition at multiple scales of society. Where many studies in the transition literature focus on the innovation of a specific technology, or groups of technologies, I expand the framework to also explore how new approaches to governance can also serve as innovations in the sustainable transition.

1.1 Guiding Framework: A Multi-Level Perspective on Sustainable Transitions

Throughout the dissertation, the sustainable transitions theory will serve as a conceptual framework by which I integrate different literatures and analytical themes to explore key questions of the sustainable transition of energy and water systems. One distinct heuristic of the transition literature will guide much of the context for my analysis. This is the concept of a Multi-Level Perspective (MLP) in sustainable transitions, which includes the elements of the socio-technical *regime, niche,* and *landscape.*

At the core of the sustainable transition theory is an attempt to understand the complex dynamics of socio-technical change (Elzen, et al). The elements and linkages of a socio-technical system is a product of the activities and social groups which reproduce them, which can either be aligned or in tension with one another. The Multi-Level Perspective (MLP) has been developed within the transition literature to describe and analyze these complex, long-term processes. It has also been used to help design policy and as a heuristic to *ex ante* assess policies to stimulate socio-technical transitions (Hodson, 2010). Under the MLP there are three primary structures of any socio-technical transition.

The first is the socio-technical regime, which refers to the ‘deep structure’ that accounts for the stability of an existing socio-technical system (Geels, 2014). Regimes (which can be conceived at the meso-level) constitute the “whole” of policy, regulatory, structural, institutional, societal and environmental systems that are inherently normative at a particular scale, and as such constitute the “system” that is evolving and changing (Geels, 2014). Regimes are often characterized as a set of semi-coherent rules that coordinate and orient the activities of the social groups and various elements of socio-technical systems. On the one hand, actors enact, instantiate and draw upon rules in concrete actions in local practices; on the other hand, rules configure actors. Examples of regime rules range from cognitive routines and shared beliefs, to lifestyles and user practices, to favorable institutional arrangements and regulations, and legally binding contracts (Elzen, et al).

Regimes account for the stability of a socio-technical system and provide orientation as well as coordination to the activities of relevant actor groups (Elzen, et al). Existing regimes are often characterized by lock-in. While science, technology, politics, markets, user preferences and cultural values have their own distinct dynamics, and are coordinated by different sub-regimes, they also intertwine and co-evolve with each other (Dewald and Truffer, 2010) When these sub-regimes are coordinated and aligned, stability remains. Under a stable regime, innovation often occurs within sub-regimes, but it does so incrementally. When these sub-regimes are misaligned, this leads to new trajectories (Geels, 2004).

In contrast, niches (which can be conceived at the micro-level) are small markets where users have special demands and are willing to support emerging innovations. While regimes generate incremental innovations, radical innovations are generated by niches (Elzen, et al). Niche actors (such as policy entrepreneurs or technological innovators) work on radical innovations in either technology or behavior that deviate from existing regimes. Niche actors aim to either integrate into the regime or even replace it (Geels et al, 2007). Niches are crucial for transitions, as they provide the seeds for systemic change. However, the niche transition is not easy because the existing regime is stabilized and because niche innovations may have a mismatch with existing regime dimensions (e.g. lack of appropriate infrastructure, regulations or markets) (Geels et al, 2007). While actors may push for change, they may often be deterred by historically established steering mechanisms and other actor groups. This can create systemic resistance to change and results in path dependencies and regime lock-in. For example, in Chapters 2 and 3 of the dissertation, I examine the electric utility as the existing regime within the current energy system and how the regulatory system, which has governed the electric utility in concert with energy markets and user preferences and cultural values, is in conflict with the niche innovation.

The socio-technical landscape (macro-level) is then the wider context, which influences the niche and regime dynamics (Kemp et al 1998). Divergences between the desired and current system states create pressure for change and corrective actions within the socio-technical system. The landscape is exogenous to the regime and constitutes the pressures that emerge from regional and global influences. Landscape pressures open up spaces within the regime for niches to evolve and change to occur. As niches accumulate and penetrate at the regime level, regimes begin to transition to qualitatively different modes of operation and behavior; i.e. the path dependencies change.

Key to understanding socio-technical innovations is the notion of niches as spaces where the viability of an innovation is demonstrated and changes in its context are being made that foster its wider diffusion against a backdrop of existing regimes (Kemp et al,1998). In the sustainability transition literature, the concept of innovation is expanded from a focus just on technological change to policy change and the co-evolutions of innovations that support transition, including behavioral and policy innovations that conflict with the presiding regime dynamics (Eltzen, et al). In many ways, policies can be both direct innovations and co-evolutions. For example, the work by Geels (2014), examines the development of carbon markets, as both individual innovations and as co-evolutions within a broader socio-technical landscape.

The Multi-Level Perspective (MLP) empirical work on sustainable transitions has shown that transitions require changes not only on the niche level, but also on the level of incumbent regimes (Raven et al, 2010). Because it is the response of regimes to niche innovations (and the niche supporters to the regimes responses) that constitute much of the dynamics of a sustainable transition, when studying any innovation and co-evolution, it is important to not only analyze the purposeful interventions by the government and other actor groups, but also counteracting steering mechanisms, which reflect power asymmetries and path dependence in the system (Raven et al, 2010). Smith (2007) argues socio-technical innovation should be understood in terms of a dynamic interweaving of both the niche and regime, which implies a focus in analysis on ‘translation processes between niche practices and regime practices’ (Smith, 2007, p. 431)

Following that argument, the relationship between the concept of the niche, regime, and socio-technical landscape can be understood as a nested hierarchy. As shown in Figure 1-1, the nested character of these concepts means that regimes are embedded in the socio-technical landscape, and the niches within the regimes. Actors in the social networks, governance, and users which support the niche work to replace the regime. The diffusion of new technologies occurs at the outcome of linkages between developments at multiple levels. Innovations can transition from the niche-level when the sub-processes at the regime and landscape level create an opportunity. System innovations therefore are not just about the technology but the surrounding markets, regulation, infrastructure, actors, and networks.

Understanding the process of how a niche innovation occurs is another aspect of the MLP. In the MLP, regime transition is intimately dependent upon influences that emerge from the landscape and niche levels, which are ultimately direct drivers as well as complex processes that are in operation at different scales and levels (Geels, 2002).

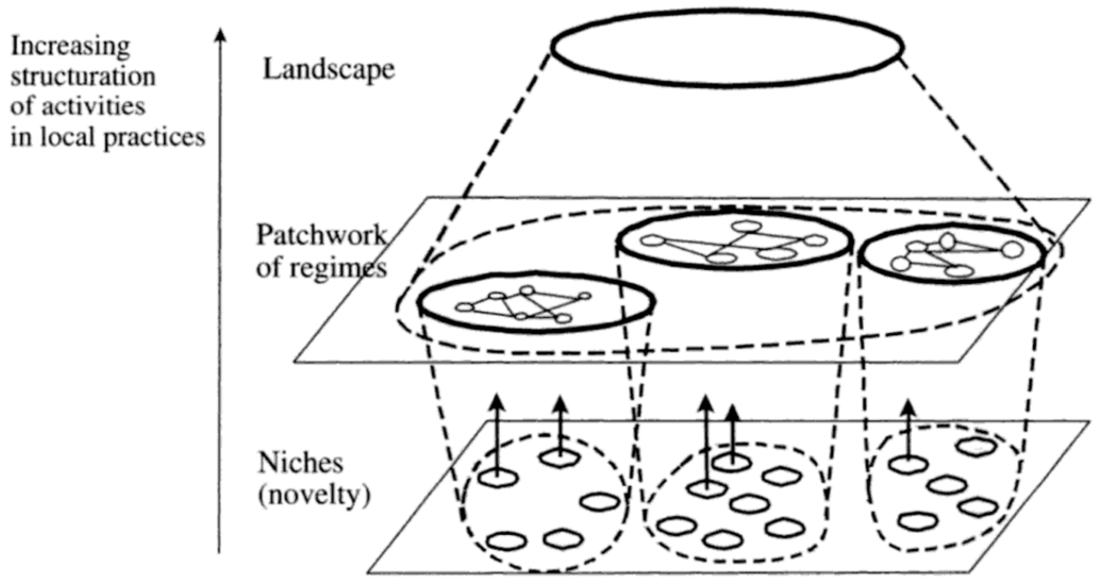

Figure 1-1 Diagram of the Multi-Level Perspective Framework (Geels, 2002, p. 1261)

Understanding how subsystems, at different scales, work to influence a regime transition continues to be a major focus of the MLP literature (Geels, 2002). However, changes in subsystems do not always equate to innovations as is conceived in a sustainable transition. Stable diffusion of technologies or behaviors points to incremental innovation trajectories and stability in the overall evolution of the system. In contrast, qualitative changes in the fundamental behavior or the structure a system indicate radical innovations and shifts in the regime (Geels, 2007). Quite simply, for true transition, there must be a qualitative change in the behavior and operations of the socio-technical landscape.

The literature on niche innovation (Kemp et al., 1998; Schot and Geels, 2008) distinguishes three core processes in niche development:

1. The articulation (and adjustment) of expectations or visions, which provide guidance to the innovation activities, and aim to attract attention and funding from external actors.
2. The building of social networks and the enrollment of more actors, which expand the resource base of niche-innovations.
3. Learning and articulation processes on various dimensions, e.g. technical design, market demand and user preferences, infrastructure requirements, organizational issues and business models, regulatory and policy instruments, symbolic meanings.

It is in these second and third core processes that much of my dissertation research is focused. Throughout my dissertation three themes of the niche-regime relationship will be explored. The first is the role of regulation and policy instruments in the sustainable transition of our energy system and their relationship to the niche-regime dynamic. The second is how the enrollment of new actors in the governance of energy and water systems and the behavioral changes of these new actors is shaping the niche-innovation development. The third, which is largely an extension of the second theme, is an examination of the role of the public in niche-innovation development and transition. All of these explorations contribute to a larger examination of whether the behavior and the dynamics of the subsystems within these core processes are actually facilitating a sustainable transition or just incremental change.

While my research is focused on the sustainable transition of energy and water systems and involves the examination of energy and water niche innovations (both technological and social/political), my interest is not on the technology or policy itself (i.e. energy efficiency policies or distributed solar photovoltaics) but rather the causal interactions between attributes or specific dimensions of the socio-technical system that guide and shape the niche innovation development. Furthermore, as explained more fully below, each case study also builds on supportive and additional relevant streams of literature to better understand the dynamics within the subsystems of a sustainable transition. Throughout the dissertation, I pull from the participatory democracy literature as well as the literature on policy entrepreneurs to help guide my examination of the innovations and co-evolutions sustainable transitions in energy and water systems. Finally, throughout the dissertation I explore the concept of scale in sustainable transitions.

1.2 Section 1.2 Methodological Approach

1.2.1 Section 1.2.1 Defining the Level of Analysis and the Units of Analysis

Sustainable transitions first happen on the micro scale (i.e. at the niche level) before moving to the *meso* and *macro* levels. To understand a sustainable transition, it is important to understand the dynamics of innovations at the niche level to identify what successful behaviors of the subsystem (i.e. institutions, policies, relationships) transition the niche to the regime. Throughout the dissertation, I take a case study approach and apply the MLP framework, in combination with other theoretical disciplines, to examine active niche innovations that are trying to transition to the regime level. All four of my case studies isolate a specific subsystem of interest to examine in the transition. In all four case studies the level of analysis, within the MLP framework, is the niche, as it exists within the larger regime and socio-technical system. The units of analysis are the subsystems, at various scales, that are working to develop the niche innovation (i.e third-party actors, regulatory process, public participation, policy framework). In some cases, these subsystems are local actors working to scale–up the niche to the regime. In other cases, these are national actors, scaling down to the local level, to develop the niche to the regime. While all case studies are distinct, across the entire dissertation my goal is to use the MLP framework to assess active phenomena with the intention of determining whether the behaviors of the subsystem in question are qualitatively changing in a way that will facilitate a sustainable transition or if there are other changes that need to occur in order to facilitate qualitative change.

1.3 Section 1.3 Applying the MLP to the Local Level

Where this body of work stands out from much of the MLP literature is in its geographical focus. Early work using the MLP was criticized for its neglect of geography and continued focus on national level transition (Smith et al, 2010; Truffer and Coenen, 2012). Truffer and Coenen (2012) argued that there was a need for a "richer special and scale conceptualization within transition studies." Similarly, Monstadt (2009) explicitly called for a greater attention to urban studies. This need for local-level analysis has been largely driven by the recognition that cities are at the forefront of sustainable transitions (Bulkeley et al, 2010; Hodson and Marvin, 2010).

Geels (2010) argues that cities themselves play three important roles in sustainable transitions at the national level. First as 'primary actors,' who enact a transition. Second as 'seedbeds and locations' for radical niche innovations in the early phase of transition. And third, in a more limited role that contributes to the coevolution of innovation and helps transform existing regimes through powerful incumbent actors and strong market interactions.

Similarly, Hodson and Marvin (2010) argue the importance of analyzing transitions at the city level in order to examine the inclusion or exclusion of particular interests or communities in the mobilization of a niche innovations. Following Hodson and Marvin (2010), studying the role of public participation at the local level can inform the role of the public at a national level.

However, there remain concerns over applying the MLP framework to the local level. As Naess and Vogel (2012) point out, the regimes in cities are often multi-segmented and are integrated across multiple scales, making it difficult to isolate and assess independent subsystem behaviors. Nonetheless there is a need to translate and adapt the MLP to the local level and integrate the elements of transition theory with other frameworks to understand urban sustainable transition (Dixon and Eames, 2014).

1.4 Section 1.4 Assessing Qualitative Change in the MLP

According to Ulli-Beer (2013) there are two core systemic properties and two dimensions in a sustainable transition that are interrelated but should be differentiated. This is an important distinction to make as it will aide in crystalizing exactly *how* to determine if the case studies presented in this dissertation are in fact examples of active sustainable transitions or just studies of incremental change. In the transition from stability to change, the two core systemic properties of interest are the structure of a socio-technical system and its behavior over time. The system structure refers to the dynamics and causalities between element- or subsystem-specific attributes. Qualitative change may emerge in the structure if new institutions or new actor networks are established. When conducting any case study into a sustainable transition, this aspect of qualitative change in the institutions, behaviors, etc. of a socio-technical subsystem is critical. As highlighted in Figure 1.2, the circular, casual dynamics within a system are important process structures that influence system behavior over time, as they help to link system structure to behavioral characteristics. Change only occurs if the process results in qualitative change.

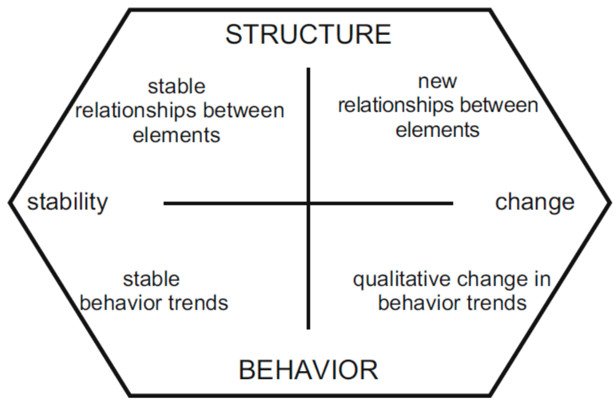

Figure 1-2 Core properties and analysis units in a Sustainable Transition (Ulli-Beer, 2013a)

Now, how to define and measure qualitative change within the sustainable literature is less clear. In this dissertation, I follow the guidance of Grubler (2012) and chose case studies where the behavioral characteristics of the subsystem of interest are in a state of change. As such the reference variable becomes the behavior of the subsystem of interest. For example, in my research examining the niche innovation of energy efficient buildings and the third-party actors working to develop the transition, I chose a case study where the behavior of the third-party actors is markedly different from its historical behavior within the policy process. As noted, while my focus is on understanding the dynamics occurring at the niche level and in the niche transition, across all chapters I broadly explore to what degree the subsystems in question are actually facilitating a sustainable transition. To that end, I explore whether the qualitative change in subsystem behaviors are resulting in structural changes within the socio-technical landscape that may enable qualitative system change.

1.5 Section 1.5 Defense of the Methods

As noted, this dissertation is a compilation of five case studies. Case study research involves intensive analysis of an individual unit and as such provides an opportunity to gain a deep holistic view of the research problem in question, and is useful when describing, understanding, or building a new area of research. Whilst case studies have traditionally been viewed as soft research, Yin argues that case study is necessary and appropriate for specific research interests (Yin, 1981).

A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 1981). The purpose of case studies is to explain a causal link, describe an intervention, or illustrate certain topics within an evolution (Yin, 1981).

Case studies are a preferred strategy when the research is asking 'how' or 'why' of a specific phenomenon, the researcher has little control over the events, or when the research focus is on a contemporary phenomenon within some real-life context. According to Schramm (1971) the essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a *decision* or set of decisions; why they were taken; how there were implemented; and with what results (Schramm, 1971). Given that the purpose of my dissertation is to explore contemporary phenomena, describe the process of change transpiring, and explore how a niche innovation transfers to a regime, case studies are appropriate.

However, by choosing to do four completely separate case studies I run the risk of producing a body of work with internal validity but very little external validity. As King et al (1994) state; “in all social science research and all prediction, it is important that we be as explicit as possible about the degree of uncertainty that accompanies our prediction” (p 212). To overcome this lack of generalizability I have attempted to pick case studies that are atypical cases within a standing literature or build directly on established work where more research is warranted.

While case studies are traditionally seen as purely qualitative, I use both qualitative and quantitative methods in my case studies. In the case studies where I employ quantitative methods, I provide thorough justification for each analytical approach within the chapter. In terms of my qualitative work, the analysis presented in two of the four case studies draws on data and information derived from historical research, semi-structured, face-to-face, interviews and field observations. The richness of the information derived from our face-to-face interviews has the strength to reveal the critical interactions of complex social phenomena (Miles and Huberman, 1994). However, qualitative case studies may suffer from what Miles and Huberman (1994) have termed the “limitations of interpretivism”—there may be a “person-specific, artistic, private/interpretive act that no one else can viably verify or replicate it (p. 281)”.

My research adopted several measures to overcome these limitations. First, the interviewees were carefully selected as actors who occupy roles or positions in the subsystem of interest and are knowledgeable about the issues studied (Johnson, 1990). Additionally, I attempted to interview as many diverse actors as possible. Second, I used semi-structured questionnaires which were developed on the basis of a thorough literature review as a way to facilitate systematic interviews across interviewees. Third, I conducted e-mail correspondence, and follow-up telephone interviews were conducted to collect supplementary information and to clarify data. Fourth, the interviews were recorded and transcribed to reduce inaccuracies due to poor recall.

1.6 Overview of the Dissertation

In Chapters 2 and 3, I examine the unfolding energy transition with an examination of the growing adoption of the niche innovation, distributed solar photovoltaic resources. The energy transition in both the United States and throughout the world has been studied from many perspectives. Scholars have examined questions related to technology diffusion (Jacobsson & Johnson, 2000; Jacobsson & Lauber, 2006), scales of change (Schreurs, 2008; Sovacool & Brown, 2009), and political backlash to sustainable energy legislation (Stokes, 2013). Here I build on work by Hess (2016), which was among the first to use the MLP framework and the dynamic of the niche-regime relationship to understand the tension between distributed solar resources, incumbent utilities, and the regulatory process that relates the two. Because the growth of distributed generation (DG) solar is dependent on regulatory policies that affect its economic feasibility, the outcome of the regime-niche relationship is highly dependent on public policy and the regulatory process (Hess, 2016). Hess (2016) outlined that more attention needs to be given to how power is controlled in sustainability transitions in non-traditional ways. As Grin et al. argues, a central challenge of transition studies is to understand how "to tilt the balance of power and legitimacy between incumbent and sustainable practices" (2011: 80).

In reviewing all the major net metering controversies over the past five years, Hess (2016) recognizes how the current transition from a regulatory landscape that has been dominated by Renewable Portfolio Standards and Net Energy Metering (NEM) to a more discrete valuation process of distributed resources presents new challenges for the niche regime. I build on this recognition and look specifically at how behavioral changes in the regulatory process, specifically the movement towards a Value of Solar (VOS) for DG solar, presents new complications to the regulatory subsystem that guides the niche-regime dynamics. First, I examine the implications of the policy instrument VOS (the subsystem) and highlight how the transition from Net Metering to Value of Solar may not result in the qualitative change necessary to facilitate a true sustainable transition but rather continue incremental change. Second, I examine one of the largest arguments made by the regime electric utility against the development of DG - the argument that DG causes a cost shift. This is supported by a case study in Georgia.

The purpose of this case study is to examine an active niche innovation of the energy system with the goal of first, examining the regulation's role in the transition and second, identifying which subsystem processes (i.e. policy instruments and regulatory structures) are facilitating innovation and which ones are not. In the absence of a federal energy policy or plan, every State in the U.S is individually engaged in a niche-regime dynamic. What is successful behavior of the subsystem in one state may not be effective in another and therefore may not translate to the national level. Furthermore, the regulations and policies that the niche supporters may perceive to be leading to innovation, may not result in the qualitative change necessary. As the sustainable energy transition is active, throughout the world, it is important to distinguish between those processes that lead to innovation and those which lead to incremental change.

In Chapters 4 and 5, I turn to understanding another core process in niche development within sustainable transitions (Kemp et al., 1998; Schot and Geels, 2008) - the enrolment of new actors in the governance process. In my first case study, I examine the strategies of intermediary actors in the policy process with the intention of understanding how the strategies of these actors are influencing the sustainability transition of urban energy systems and the niche innovation of more energy efficient buildings. In the second case study, I expand my definition of niche innovation from a technology (i.e. solar or energy efficiency) to include a new structure for water resource management. Here, I explore whether the niche of collaborative resource management and in inclusion of public participation in the governance process (which I define as grassroots stakeholders) can transition from being a successful tool for small-scale watershed management to large-scale resource planning.

The first case study explores the role and strategies of third-sector intermediary actors in the sustainable transition of energy systems in cities. As cities are increasingly becoming the thought leaders and drivers of the sustainable transition, it is critical to understand the governance structures and dynamics that are driving the transition. In this work, I examine the strategy of 'strategic capacity seeding' (Clark, 2017) by third-sector intermediaries as a subsystem working to develop the niche innovation of energy efficient buildings in the local sustainable transition process. I focus on how third-sector intermediary actors are shaping local institutions in the sustainable transition and the role of public participation. As Hendriks (2009, p. 341) has observed, '[r]ecent debates on how to "manage" policy transitions to sustainability have been curiously silent on democratic matters, despite their potential implications for democracy'.

I use a case study of Atlanta, GA to explore the strategies of third-sector intermediaries in the sustainable transition as well as the implications of the coevolution for local institutions, institutional capacity, and the role of the public in the policy process. My research suggests that the strategy of strategic seeding can provide immediate benefits to the municipality, in terms of reducing resource barriers, but it is unclear whether or not it has any lasting qualitative impact on the institutions that govern municipal energy policy. Furthermore, there may be a need to consider more actively the role of the public in the policy process. Whether the strategies of intermediaries will facilitate the qualitative change of the institutions necessary for niche innovation is unclear. But understanding how these dynamics work in the city will be critical in determining how to translate the city level innovation to a national scale.

The second case study continues the theme of examining the behavioral changes of third-party actors and the role of public participation in sustainable transitions. However, in the second case study I expand the use of MLP from focusing on a technological evolution to examine the inclusion of local actors in the management of large-scale water resources as the niche innovation in the sustainable transition of water systems. The literature on sustainable water resource management continually points to the need for including local actors and local users in the management of water resource (Ostrom, 2009). While there are multiple cases of this 'commons' approach working at the watershed level, there are few cases of governance models where local, grassroots actors are included in the management and planning of large-scale resources, that cross multiple political and geographic boundaries. In this chapter, I extend the MLP framework to treat the governance model of collaboration and public participation in the governance process as the 'niche' innovation that struggles to be integrated into the established management regime - which is dictated by centralized legal battles and failed cooperation between user states. I apply the extended MLP framework to a case study on the Apalachicola-

Chattahoochee - Flint (ACF) water wars. The subsystem of interest is the emerging actor of the ACF Stakeholder group- a grassroots, non-government organization working to develop a platform for local interests in large-scale resource management.

Where the first case study examined the role of large, national non-state actors in the local policy process, the second case study examines the role of a small, local non-state actor in a state and federal policy process. This second case study was originally the primary research endeavor of my dissertation but, due to the politically sensitive nature of the topic, I was unable to finish the research. What is presented here is the work to date.

Chapters 4 and 5 also share two core analytical themes. First, both draw attention to the role of actors and their agency in sustainable transitions. These niche and intermediary actors are in many respects policy entrepreneurs and at the forefront of this transition, as a driving force for niche development and transition. As O'Neil and Ucbasaran (2016) recognize, these entrepreneurs may represent a new type of entrepreneurial behavior combining economic, environmental and social aims to shape the institution of a sustainable transition. As such, I utilize the literature on policy entrepreneurs in both case studies to examine the institutional elements shaping these subsystems and to understand how these actors are shaping the niche development which they either constitute or support.

The second draws attention to the recognition that from a governance perspective, the sustainable transition literature views the engagement of a wide variety of stakeholders in policy development as a necessary element, yet has paid relatively little attention to public participation in socio-technical change (Upham et al., 2015). In concert with understanding the behaviors of non-state actors in the niche innovation, it is critical to understand how these actors may shape how participatory democracy operates within a transition. Furthermore, it is important to explore at which stage in the transition the public is effective. While the literature on sustainable resource management continually recognizes the need for public engagement, more research is need to understand how public support for a niche innovation translates to the regime.

In both case studies, I follow a similar methodological format. Recognizing the importance of combining other fields of research for analyzing sustainable transitions (Avelino et al, 2016), I build hypotheses pertaining to my research questions by combining the literature of sustainable transitions with other relevant literatures. While the overarching lens by which I examine these cases is within the context of sustainable transitions and the MLP, I build my hypotheses from relevant supporting literatures, mainly participatory democracy and policy entrepreneurship among others. Second, I utilize in-depth semi structured interviews with relevant actors to explore my research questions and test my hypotheses. In my second case study, I developed and operationalized a survey to also test my work but did not receive enough responses to justify statistical significance.

Chapter 6 moves beyond examining active subsystems and processes within the energy and water subsystem to explore the potential for a qualitative shift in the governance of energy and water and the isolated niche technologies of each system. Here, I return to the city and combine the MLP framework with the Water-Energy-Climate Nexus to examine the potential for the adoption of a 'nexus' view in local policy instruments to support the niche innovation of distributed energy resources.

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CHAPTER 2. THE ROLE OF NICHE REGULATORY POLICIES IN SUSTAINABLE ENERGY TRANSITIONS: A CASE STUDY OF NET METERING AND VALUE OF SOLAR

2.1 Introduction

In the United States, the effort towards a sustainable transition of the electricity system away from dependence on fossil fuels has become a highly divided and political process. A sustainable transition requires substantial changes in electricity regimes that result in resistance from the incumbent utilities (Geels, 2014). This tension is evident in the conflict between the incumbent U.S electricity system regime and the growth of distributed energy resources (DERs), specifically the growth of the niche technological innovation, distributed solar photovoltaics (DGPV). The literature on sustainable transitions has given significant attention to the transition of the electricity system and the role of regulatory policies. Elzen et al. (2011) argues that a successful transition of the electricity system requires not only a technically and economically feasible technology mix but also the alignment of these factors with political conditions such as regulatory openings and normative pressures.

The growth of DGPV is dependent on regulatory policies that affect its economic feasibility, user adoption, and ability to compete against incumbent technologies; furthermore, the outcome of the regime-niche relationship is highly dependent on the structures of regulatory frameworks and the supporting policy decisions. Therefore, understanding the specific dimensions of regulatory policy as it relates to the development of niche innovations is critical to understanding how to foster sustainable transitions (Hess, 2016). This research builds on prior research that recognizes the need to include greater attention to the impact of regulatory decisions and how they shape the sustainable transition of our electricity system (Avelino and Rotmans, 2009; Geels, 2014; Jiusto and McCauley, 2010; Kern and Smith, 2008).

After a background section that reviews the conceptual framework and the history of solar energy policy in the U.S., I turn to analyzing the role of regulatory policies in the sustainable transition of the U.S electricity system, focusing on the two policies of Net Metering (NEM) and a Value Solar Tariff (VOST). In this chapter, I explore several policy implications related to NEM and VOSTs, including-the functional differences between the use of NEM and the use of VOST; the challenges facing implementation of a VOSTs; the consequences associated with the methodologies employed to determine a VOST; and the overarching challenge of regulating the value provided by a niche technology in a market dictated by the cost structure of the regime. I then demonstrate how the framework and methodological decisions made in a value of solar (VOS) study can greatly impact the resulting VOST. I use a case study in the state of Georgia using public electricity generation and electricity demand data for the Georgia Power Company (GPC) as well as environmental and generation data from multiple state and national databases. In the Chapter 3, I will use these VOS calculations to build on the work by Hess (2015) and examine one of the major regime arguments against the niche growth of DGPV- the strategy of characterizing DGPV as an economic burden on non-solar customers. This argument is often referred to the ‘cost shift’ argument. In conclusion, I provide a discussion and additional thoughts on the role of the regulatory structures in the sustainable transition of our electricity system as well as policy implications of the current approach and suggestions for further analysis.

2.2 Analytical Framework

In this chapter I use the Multi-Level-Perspective framework as a heuristic to diagram the technical, economic, and political dynamics of a sustainable transition of the U.S electricity system (Need to includes refs here, unless this is your own framework). The MLP framework distinguishes between three analytical levels with increasing temporal stability. The first is the niche. The niche is the level at which innovation occurs and is characterized by a flexibility and uncertainty. The regime is the presiding stable set of practices, technologies or rules that have been legitimized through institutional and technological lock-in (Geels, 2014; Brown, et al., 2007). The sociotechnical landscape contains the slow-moving societal processes that provide the context for regime stability or change. Sustainable transitions, defined as regime change, occur through the interplay between niche innovation, internal regime change and landscape factors (Geels, 2014).

Applying the MLP to the electricity system in the United States, the regime consists of three interlinked dimensions (Geels, 2005): (a) network of actors and social groups; (b) formal, normative and cognitive rules that guide the activities of actors; and (c) material and technical elements. In this chapter, I am focused on the formal rules that guide niche development, specifically regulations and the utility business model.

According to Verbon and Geels (2007) electricity regimes are characterized by path dependence; resulting from stabilizing mechanisms which include regulations and standards that stabilize the economics of the regime and existing machines, and infrastructures (i.e power plants) that stabilize regimes through sunk investments and technical complementarities between components (Unruh, 2000; Walker, 2000; Brown and Wang, 2015).

The niche is the micro level where niche technological innovations emerge. In the context of this research, the niche innovation is distributed solar photovoltaics. Niche policies work to develop innovations through multiple policy spaces so technological innovations can be incorporated or can overthrow the regime. Niche policies are necessary as the incumbent regime is often resistant to niche growth and will employ several strategies to stifle adoption. This is especially true for electric utilities, that are historically opposed to innovation. For example, over the past ten years, on average electric utilities in the United States have spent less that 1% on R&D (NRI, 2015). In this chapter, I focus on the supportive niche policies of net metering and value of solar tariffs.

The socio-technical landscape then represents the socio-economic, cultural, and environmental context in which the niche-regime relationship exists and in which policy plays out (Brown and Sovacool, 2011). In the context of electricity system, the landscape represents the national and international trends, macro-economic patterns, the totality of infrastructure, and political cultures that are even beyond the direct control of the regime and niche (Grin et al. 2010). Such examples include concerns over climate change, energy access, resource scarcity, energy security, migration, wars, and economic development patterns (Brown and Sovacool, 2011). The dynamics of the landscape level, shape the dominant economic and political discourses, and influence the patterns of behavior of actors within the regime and outside the regime. Figure 2.1 outlines the relationships between these levels.

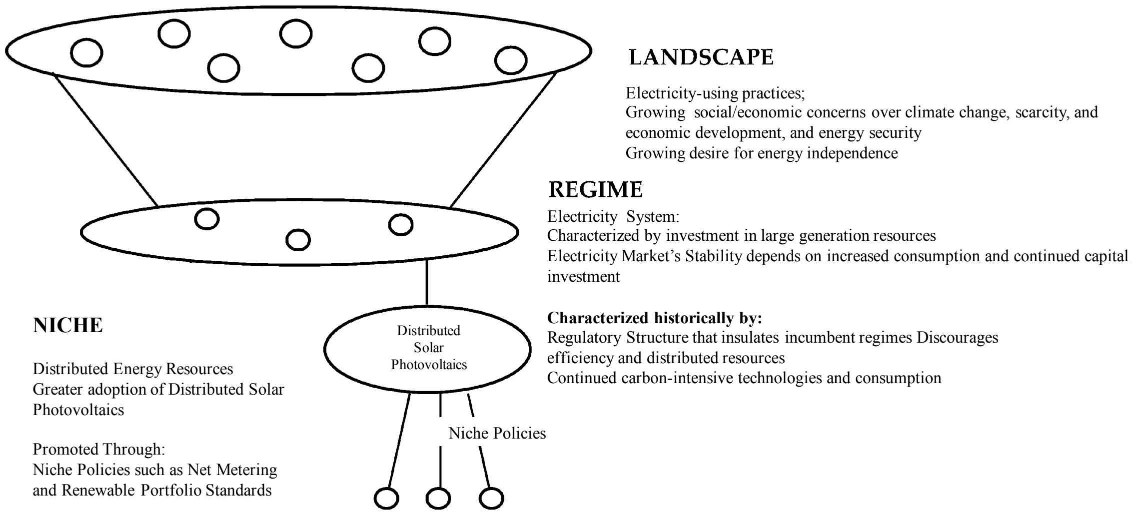

Figure 2-1 The multi-level perspective (landscape, regime, niche) and corresponding dynamics in the context of the U.S Energy System

2.3 Research Questions

The purpose of this chapter is to answer four primary questions.

RQ1. What are the market and policy differences between the niche the policies VOST and NEM?

RQ2. What are the policy implications of utilizing a VOST for niche innovations and the sustainable transition?

RQ3. How does the framework, inputs, and methods utilized in a VOS methodology impact the VOST?

RQ4. What is the value of distributed solar in Georgia and how do estimates of a VOST vary based on different methodological assumptions?

To answer these questions, first I examine the literature on VOST and NEM and outline the critical role of regulators in the adoption of niche technologies as well as how the lock-in of the incumbent utility business model creates major barriers for niche development. I then examine how the valuation methods as well as how the dynamics of the electric utility, the decisions of policy makers, and the policy structure can result in varying estimates for a VOST. To this end, I explore the implications of these dynamics within the niche regime relationship and the pace of the sustainable transition. Second, I provide a basic estimate of a VOST for the state of Georgia, using DGPV production information in conjunction with public GPC financial data to assess the value of power exported from behind-the-meter (BTM) DGPV to GPC. I assess a VOST under three different discount rates and three different scenarios for the components of avoided energy costs, avoided generation capacity costs, and with or without the inclusion of societal and environmental benefits.

2.4 Background: History of Solar Policy in the United States and Framing the Dynamics between Net Metering and Value of Solar

While in some areas of the country, electricity generation, transmission, and retail sales are divided among separate organizations, that are increasingly guided by market competition forces, other states are dominated by utilities which still function under the incumbent, integrated model. Though few in number, these investor-owned utilities (IOUs) service the largest number of customers in the United States (DOE/QER, 2016). In this chapter, when I refer to the electric utility, I am referring to IOUs. IOUs are regulated by a state's public utilities commission (PUC) as regulated monopolies. PUCs, or their equivalent in each state, are a replacement for the competitive market. In exchange for granting the exclusive right to sell electricity in a given service territory, PUCs determine how much the utility is allowed to invest using ratepayer resources (and in what), how much it can charge, and what its profit margin can be. Often referred to as the "regulatory compact" and first laid out in the Binghamton Bridge Supreme Court case of 1865, this legal structure has given PUCs mechanisms to define the market for electricity in a state. (Jamison, 2005)

The revenues and the profits a utility earns is also determined by the PUC. PUCs determine a utility's total revenue requirement, which represents the amount of money a utility must collect in order to cover its operating costs and make a guaranteed profit. The PUC decides what the revenue requirement will be based on a number of factors, but generally speaking it is comprised of the value of a utility's capital assets multiplied by the allowed rate of return (i.e the guaranteed profit) plus some additional operating and administrative expenses. The allowed rate of return (the return on capital assets) drives a utility's profitability.

An inherent downfall of the 'regulatory compact' approach is that it incentivizes investment in assets over efficiency and services, research and development, and (more importantly for this analysis) dictates the value of electricity not in terms of market forces but in terms of a single monopoly's investment patterns. By having a set rate of return, the only way for utilities to increase their profits is to increase rate base, which is tied to capital investments. This essentially incentivizes utilities to make large investments, even if unwarranted, and pass any and all costs on to customers. In other words, the more assets a utility acquires, the more profits grow. And the only way to justify continued asset investment is through continued growth in demand. Of course, under a regulated monopoly model, there is no alternative for the customer as the utility is the only game in town. The growing adoption of DGPV, fundamentally challenges the incumbent electricity regime.

The conflict between DGPV and the utility industry in the U.S. dates back nearly half-a-century. In the 1970's and 80's, the emerging green-transition coalition emphasized that DGPV provided citizens with local control over their electricity use (Laird, 2001), a vision that contrasted with the utilities' desire to maintain exclusive and guaranteed control over the electricity market (Lipschutz and Mulvaney, 2013; Reece, 1979) and a vision that is still espoused by DGPV advocates today. When unable to win favor federally, the green transition coalition shifted its attention to state governments, which by the early 1980s were already developing renewable portfolio standards and net metering laws to help incentivize DGPV adoption (Lipschutz and Mulvaney, 2013).

Net metering is a compensation mechanism that credits solar energy system owners for the electricity exported to the grid. There are two primary forms of net-metering in existence in the U.S. The first, and the one focused on in this chapter, is retail rate net metering (NCSL, 2016). Retail-rate NEM credits solar system owners for the electricity they export to the grid at full retail rate. The second is non-retail rate NEM which compensates exported power at rate lower than retail rate, typically at the utilities avoided cost rate.

NEM rules vary from state to state. Some of the common differences between states include the capacity limits on qualifying systems and the ownership of renewable energy credits. In most jurisdictions, NEM is treated as a compensation mechanism where any exported energy is treated as a credit against the owner's next bill cycle. Typically, customer's monthly net excess generation is carried forward at the utility's retail rate to a customer's next bill for up to 12 months. At the end of a 12-month billing period, the utility either pays the customer for any remaining unused credits or the credits are lost (NCSL, 2016).

From the early 1980's until 1996, there was a slow increase in net metering laws at which point the rate of state government support grew rapidly based on a regional diffusion pattern (Stoutenborough and Beverlin, 2008). Then the Energy Policy Act of 2005 required state electricity regulators to "consider" rules that mandate public electric utilities make available upon request net metering to their customers (Verzola, 2015). By 2016, 38 states had NEM policies, and 29 states had mandatory renewable portfolio standards, with voluntary standards in seven other states. Additionally, many states adopted various financial incentives to support the deployment of DGPV, including property, sales, or income tax incentives for system purchasers, grants or rebates, third-party financing, low- or zero-interest loans, or feed-in tariffs requiring utilities to purchase solar energy from producers at an above-market rate (DSIRE, 2016).

While NEM laws are now widely diffused, they are not without limits. In about half of the states with NEM, there is a subscriber limit for DGPV, generally in the range of 1–5% of peak demand. As such, current NEM laws are a perfect representation of supporting niche policies as they are designed specifically to grow a market to the 'acceleration stage' where niche innovations enter the mainstream market and start to compete with the incumbent regime, but are intended to provide support during the final phase of diffusion when the market transformation does not require further public assistance (Hess, 2015).

Due to a supportive niche policy landscape coupled with continued cost reductions, the residential solar market has grown from a few MWs in 2010 to over 2.5 GWs in 2016 (Wood, 2016). However, as DGPV adoption grows, so too does resistance from the incumbent regime. The leading utility argument against DGPV is that solar customers are not paying their 'fair share' of the costs to maintain the grid infrastructure and are inherently causing non-solar customers to recover those costs, creating a cross-subsidy. Utilities contend that the increased use of DGPV could reduce utilities' revenue to the point that they cannot pay off existing capital investments, resulting in lost revenues and potential stranded assets (Raskin, 2013; Johnson, et al. 2017). Under the 'regulatory compact' model, in order to continually earn a profit, utilities will need to shift the recovery of these lost revenues on to non-solar customers. These arguments, while often exaggerated (Johnson et al, 2017) are a consequence of the fundamental conflict with DGPV and the incumbent regime-the utility business model, which is locked-in by regulatory policies. This 'cost-shift' argument has been at the forefront of much of the recent effort by utilities to reduce or eliminate NEM and RPS's and implement standby charges on solar customers.

Thirteen states have introduced bills to repeal RPS (Plumer, 2013), with West Virginia repealing its RPS in 2015 (Light, 2015). Multiple utilities have challenged the use of net-metering programs, either through direct repeal or by implementing stand-by charges, which allow utilities to levy a monthly fee to owners of solar PV systems to undermine the financial incentive provided by net-metering (Warrick, 2015). In 2011, Virginia became the first state to allow these charges, and by 2016, dozens of utilities throughout the country were engaged in regulatory proceedings to initiate stand-by charges for residential net-metered systems (Virginia State Corporation Commission, 2014; North Carolina Clean Energy Technology Center, 2014; Turkel, 2014). Utilities' pursuit of standby is supported by their argument that an expansion of

DGPV will result in revenue erosion and an inadequacy of cost recovery for the utility, resulting in a cross-subsidy between solar and non-solar customers. This argument is usually referred to as the ‘cost shift’ argument.

It is important to recognize that the rise in adoption of DGPV corresponded with (and has contributed to) a change in demand growth. States throughout the country have been experiencing flat to declining load growth as a result of changing economic demographics, which presents an additional challenge to the utility business model (EIA, 2017). Without demand growth, utilities must find other ways to continually ensure upward profits and consistent returns. From a sociotechnical perspective, changes in demand based on shifts in the economy and user preferences represent the landscape pressures, whereas the growth in DGPV is a bottom-up niche innovation that is putting pressure on the regime utility model.

Now PUCs throughout the country are engaging in regulatory debates over the rising use of DGPV, the supportive NEM policies that have fostered the adoption of DGPV, and the arguments made by incumbent utilities about the negative consequences of DGPV. At the crux of this regulatory debate is how to incorporate the power generated by DGPV owners for any electricity that is exported to the grid, into the incumbent regime market, i.e the utility business model. This issue of determining how to best structure the electricity market for DGPV and compensate owners accordingly for their exported energy reveals a fundamental impediment to the sustainable transition and the embeddedness of the regime in incumbent policy structures. Valuing customer-sited energy assets in a market that is dominated by regulated monopolies whose business model is dictated by large capital investments and increasing demand, presents a host of 'wicked' challenges. [1]

In response to the debate over NEM, PUCs are exploring a number of different niche policy instruments. For the purpose of this research, I focus on the development of a VOST, as it is a perfect case to illustrate the importance of regulatory decisions in the sustainable transition. Similar to NEM, a VOST is a rate design policy that provides solar generating customers with credit for the electricity generated by a DGPV system. Solar customers can generate power for and take power from the grid. However, instead of tying compensation to retail rates or utility's avoided costs, a VOST requires utilities and regulators to evaluate and determine a 'value of solar,' and establish a method to govern the market value of distributed solar energy. A VOS methodology seeks to quantify the costs and benefits of distributed solar to the electricity system, the presiding utility, and society at large — the summation of which is intended to reflect the market value of the generation provided by distributed solar. A Value of Solar tariff (VOST) is the compensation provided to DGPV customers by the utility based on the VOS methodology. Currently there are only two VOSTs in practice, Minnesota and Austin, Texas, but several states are engaging in the value of solar methodology (NCSL, 2016).

[1] Rittel and Webber (1973) explained that the problems of modern society and public policy are often 'wicked' as they are 'ill-defined', interlinked, and relying on political judgments rather than scientific certitude. Wicked problems are inherently complex, resistant to a clear statement of the problem and resistant to a clear and agreed solution.

Determining a VOST requires a detailed understanding of the specific costs and benefits that DGPV provides to the utility. There have been a wide-range of efforts by non-profits, academics, technical consultants, and state and federal agencies to establish a VOST for specific utilities. However, to date, there is no uniform methodology for assessing the VOS or determining a VOST. While some studies focus strictly on how DGPV relates to the cost structure for the presiding electric utilities only (E3, 2012; Hoff, 2006) others include broader societal and environmental impacts (Perez, 2012; Jones, 2012; Rabago, 2013).

Utilizing a VOST as a regulatory tool is fundamentally challenging from both a process and an implementation perspective, and underscores the influence of regulators in the sustainable transition. The components included in the valuation process, the valuation methods, and the guiding frameworks vary significantly throughout the literature, which can create confusion and the opportunity for regime resistance to the use of VOS studies in the regulatory process (Hess, 2015). The lack of consistency in the components and methods used in the valuation process essentially leaves the decision of how to value DGPV to the discretion of the PUC.

The components assessed in a VOS study, and how they are assessed, have consequences not only for the economics of DGPV and the adoption of DGPV in the market, but also for the institutions that govern and influence the electricity market in a sustainable transition impacted by the continued dynamics of the niche-regime relationship. Many utilities have argued that the VOS should be limited only to the economic value DGPV provides to the utility cost structure. Solar advocates argue that DGPV should be assessed for its value outside of avoided utility costs. The challenge for regulators is determining which goods and services provided by solar should be ascribed value, how to value them, and then how to structure a market for compensation. Ultimately, each decision made in the valuation process reflects on the regulator's view of the role and importance of DGPV, their commitment to the regime structure, and their preference on the role of future customer owned electricity assets in the sustainable transition. From a sociotechnical perspective, the introduction of VOST represents a regulatory opportunity in the transition of the electricity system, from one characterization of the electricity market to another, and a pivotal role for regulation. PUCs throughout the country have the power to utilize a VOS to fundamentally change the regulatory lock-in of the utility system and facilitate niche transition or accept incremental improvements on the niche policies of DGPV. Similar assessments of the lock-in aspects of PUC regulation were debated in comprehensive regulatory hearings and deliberations in the 1990s with respect to the role of utility investment in energy-efficiency programs. The result was a series of well-defined cost-effectiveness tests that span an array of different utility and societal costs and benefits, beginning with the California Standard Practice Manual and ultimately resulting in a set or international protocols (Brown and Wang, 2015). Distributed solar is now in need of a similar set of well-honed evaluation principles and metrics, which the VOST debate is beginning to develop.

Instead of introducing a good to a market of buyers or sellers, a VOST requires regulators to determine the confines of the market. Regulators must decide whether to value DGPV strictly based on the cost structure of presiding utility or if to include other value streams such as environmental, social, human health, and economic benefits of solar — including reduced water use, reduced carbon emissions and local pollutants, and job growth. In many cases the local policy landscape may dictate which components are recognized in the valuation, but in any case, a VOS methodology will explicitly reflect the values of the PUC and set precedence for how to structure a market for customer-sited resources. These power dynamics could have multiple implications for future energy resources in an era of electricity generation that is becoming increasingly more distributed and disaggregated.

If executed to reflect the value of DGPV to society, a VOST has implications for the niche-regime relationship as the implementation of a VOST inherently recognizes that customer-sited solar has a market value beyond individual customer benefits. The implementation of retail-rate NEM was, and continues to be motivated by the public's desire to incentivize the adoption of customer-sited solar. NEM never had the purpose of creating a market for exported solar energy and there is a significant difference between initiating a niche policy with the intention of incentivizing technology adoption and a policy which attempts to define the market value of a technology. A VOST could be a tool for creating an entirely new market. By ascribing market values outside the regime, but to the multiple attributes of a resource, the implementation of a VOST challenges the traditional market for electricity generation and the business model between the utility and the customer from a one-way contract to a two-way contract. This could have policy implications for other technologies and resources, including energy efficiency and demand response, although well-debated protocols have already been developed. This could also hold greater policy implications for how the future electricity market is structured in terms of market players and regulatory models.

However, if the VOST is executed within the confines of the utility business model (i.e limited to the costs and benefits of the utility value stack) this inherently discourages competition between the niche and the regime and rather ties all value of the niche innovation to the incumbent regime. Unfortunately, while there are some instances of VOS methodologies that include components that are not part of the utility value stack, overwhelmingly how a VOST is determined is by dictating the value of DGPV by the utility cost structure (Hess, 2015).

Additionally, a VOST opens the opportunity to incorporate the values of the user. Under a NEM structure, the value of solar powered was capped by retail cost of electricity generated by the regime (often powered by fossil fuel generation resources). It may be that users throughout the country would willing pay more for solar generated electricity than for fossil-fuel generated electricity but this market preference is not reflected in the valuation process. In fact, we see this very dynamic playing out in other areas of solar policy, such as community solar or green-riders, where utility customers are willingly paying more to get solar energy.

Ultimately, the question for PUCs is one of purpose in the sustainable transition. The policies employed for DGPV hold weight for more than just a single technological development but for the institutions that shape our electricity system and underscore the role of regulatory bodies in the transition. Depending on the PUC, the implementation of a VOST could challenges the traditional market and utility business model for electricity generation and could have greater regulatory and market implications, or could result in simply incremental change to policies guiding the niche-regime relationship. Given the opportunity that a VOST holds, more research is needed to understand the complexities concerning policy design and implementation.

2.5 Understanding a Value of Solar Methodology and Value of Solar Tariff

VOS methodologies establish a formula and a framework for assessing the per kWh market value of customer-sited distributed solar. Since the current electricity market does not provide an arena for customers to sell their generated power, the off-taker of any solar generation (not used on-site) must, at least for now, be the utility. Therefore, a VOS methodology must take into consideration the unique nature of the presiding utility. A VOS also must quantify the multiple economic, environmental, and public costs and benefits to the greater society. Generally speaking, the values represent the benefits associated with avoided costs to the utility and the society as well as any costs of incorporating solar into the utility system. These value streams are added together to arrive at a single VOST, expressed in cents per kilowatt-hour. The VOST is then used to compensate customers for electricity generated by DGPV systems.

While there is no uniform approach to a VOS methodology, there are congruencies between the multiple existing studies (Acadia, 2015a; Acadia, 2015b; NREL, 2014: NREL, 2015). The National Renewable Energy Laboratory's 2014 report (Denholm, et. al, 2014) examined various solar valuation methodologies, concluding that the main components being valued, include:

- Energy
- Emissions
- T&D loss savings
- Generator capacity
- T&D capacity
- Ancillary services
- Environmental impacts
- Fuel price hedging
- Diversity
- Market price suppression
- O&M costs
- Integration costs
- Grid support services and Resiliency

In principle, the VOS methodology will result in a real value for the electricity generated by DGPV systems. However, there is disagreement between stakeholders in the valuation process on which value streams are legitimate. Some categories of value, such as avoided energy costs and avoided line losses are not controversial, and there is general agreement among a variety of stakeholders on their inclusion in the VOS methodology and how they should be calculated. There is significantly less agreement on overall approach to estimating other categories, including capital and operating investments in electricity generation, transmission, and distribution, or financial and security risk (Hansen, 2013).

DGPV advocates argue that since DGPV generates during daylight hours and on average generates in greater quantity during summer months, DGPV is particularly valuable to summer-peaking electricity systems as power from DGPV is produced disproportionately at times when the value of electricity is high.[2] Because PV power is generated on-site, line losses are avoided. Additionally, because power from central station generation requires significant investment in transmission and distribution infrastructure, by utilizing DGPV located near or at load, the investment in transmission and distribution could potentially be reduced if more power were generated on site (Cohen 2015).

Utilities argue that DGPV is not a reliable resource and therefore cannot be depended on consistently to reduce capacity investments or defer costs to the transmission and distribution system or management of the grid. Additionally, utilities argue that when DGPV is connected into the distribution systems, it changes the power flow conditions: instead of power flowing in one direction it can now transfer from one customer to another, or from customers back to the transmission system. At high penetrations of DGPV, this can result in thermal stress on the distribution system as well as voltage fluctuations that may be difficult to manage at times of

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[2] Electricity value is higher when system demand is high both because the wholesale price of electricity is greater and because the proportion of power lost during electricity transmission and distribution increases with the total amount of power flowing over the lines.

high loading. For example, Pacific Northwest National Laboratory recently analyzed the impact of DGPV on Duke Energy's system in North Carolina and found minimal impact to the stability of the electricity grid so long as DGPV remained less that 20% of peak load (Lu, et al., 2014) These engineering issues have created concern among distribution engineers, regulators and researchers as to how distribution systems will accommodate very high penetrations of PV – and what the associated costs will be (Cohen 2015).

Of course, solar advocates argue that there are many benefits that DGPV can provide to the distribution system including: resistive losses; deferred capacity investments; reduced transformer aging; and if utilized effectively, voltage regulation. Several studies have assessed the engineering impacts of PV in distribution systems (Quezada et al.,2006; Shugar, 1990; Woyte et al., 2006; Thomson and Infield, 2007; Navarro et al., 2013; Wid´en et al., 2010; Hoke et al., 2013; Cohen and Callaway, 2013; Cohen, 2015). Cohen (2015) is one of the few studies to translate the full range of engineering impacts into economic values, finding that DGPV has relatively little impact on the distribution system and can, in certain areas, provide substantial value.

Additional categories, such as environmental and social benefit of DGPV, elicit much more debate among stakeholders. Utilities often argue that all environmental, societal, or economic benefits are peripheral to their costs models are not relevant for a VOST. Solar advocates argue that all values provided by DGPV should be recognized whether or not these values accrue directly to the utility or to society at large (Hansen, 2013).

Recently, a few public service commissions have engaged in studies weighing both the benefits and costs of DGPV, with varying results. A 2014 study commissioned by the Maine

Public Utilities Commission found that DGPV has a has a net value of US$0.33 per kilowatt-hour. A 2013 study by the Vermont Public Service Department (Vermont Public Service Department, 2013) found a statewide net cost/benefit of essentially zero for DGPV systems installed in 2013. A study commissioned in 2013, by the Arizona Public Service, accounting for a full range of costs and benefits, found that current DGPV provided a net benefit of around US$.08/kWh (Beach, 2013). Minnesota's VOS methodology estimated DGPV to have a value of US$0.14 per kilowatt-hour. Whereas, Austin's VOS methodology originally estimated DGPV's value, at US$0.13 per kilowatt-hour. Finally, a recent study for the Public Service Commission of Mississippi found a range between a net cost of around US$0.02 per kilowatt-hour to a net benefit of about US$0.06 per kilowatt-hour, depending on scenario assumptions, such as changes in future natural gas prices (Synapse, 2015).

There are also a handful of valuation studies, mostly utility-sponsored, that have focused strictly on the costs of increasing net-metered DGPV. A 2011 report by the Virginia State Corporation Commission examined the potential costs of increasing net-metered distributed solar power to 1 % of each utility's peak load, crediting solar with only the avoided generation costs plus a small amount of avoided generation capacity costs. The study found a net cost to utilities of US$0.03 per kilowatt-hour of solar energy produced, which when spread across the entire customer base would only increase average annual customer bills by less than 0.5 % (Pitt D, 2014; Virginia State Corporation Commission, 2011). A 2010 study conducted for NV Energy found that net-metered DGPV could create a net revenue shift of between US$6 million and US$10 million, assuming a market penetration of 1 % of total statewide energy generation, which works out to approximately US$5–US$8 per customer per year or less than .4%. At higher market penetration levels of 9 and 15%, the revenue shift is estimated at US$50 million to US$150 million, or about US$40 to US$125 per customer (Navigant, 2010; NV Energy, 2015).

Additionally, multiple independent studies have assessed the costs and benefits of solar (Acadia, 2015a; Acadia, 2015b; Hoff, 2012). Table 2.1 provides a list of the major valuation components presented in the literature and the range at which each was valued.

Table 2-1 Recognized Value Streams in VOS Methodologies

Potential Benefits to the Utility	Description	Min- Max	Average	Year Range for Estimate
Avoided Energy	All fuel, variable operation and maintenance emission allowance costs and any wheeling charges associated with the marginal unit	2.9-12 c/kWh[13]	6.2 c/kWh	2008-2015
Avoided Generation Capacity	Contribution of distributed generation to deferring the addition of generation capacity resources, including those resources needed to maintain capacity reserve requirements	.01-7.2 c/kWh[1]	2.8 c/kWh	2008-2015

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[3] Xcel Energy, Inc. (2013). Costs ad Benefits of Distributed Solar Generation on the Public Service Company of Colorado System. May 2013.; SAIC (2013) Updated Solar PV Value Report. Arizona Public Service. May, 2013; Beach, R., McGuire, P., (2013) The Benefits and Costs of Solar Distributed Generation for Arizona Public Service. Crossborder Energy May, 2013. Norris, B., Jones, N. *The Value of Distributed Solar Electric Generation to San Antonio.* Clean Power Research & Solar San Antonio, March 2013; Beach, R., McGuire, P. (2013) *Evaluating the Benefits and Costs of Net Energy Metering for Residential Customers in California.* Crossborder Energy, Jan. 2013; Rabago, K., Norris, B., Hoff, T.(2012) *Designing Austin Energy's Solar Tariff Using A Distributed PV Calculator.* Clean Power Research & Austin Energy, 2012.; Perez, R., Norris, B., Hoff, T. (2012) *The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania.* Clean Power Research, 2012. Mills, A., Wiser, R. (2012) *Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California*. Lawrence Berkeley National Laboratory, June 2012; Energy and Environmental Economics, Inc.(2012) Technical Potential for Local Distributed Photovoltaics in California, Preliminary Assessment. March 2012; Energy and Environmental Economics (2011), Inc. California Solar Initiative Cost- Effectiveness Evaluation. April 2011; R.W. Beck, Arizona Public Service (2009) *Distributed Renewable Energy Operating Impacts and Valuation Study.* Jan. 2009; Perez, R., Hoff (2008), T., Energy and Capacity Valuation of Photovoltaic Power Generation in New York. Clean Power Research, March 2008; Contreras, J.L., Frantzis, L., Blazewicz, S., Pinault, D., Sawyer, H., (2008) *Photovoltaics Value Analysis.* Navigant Consulting, Feb, 2008; Benjamin L. Norris, Philip M. Gruenhagen, Robert C. Grace, Po-Yu Yuen, Richard Perez, and Karl R. Rábago (2015) *Maine Distributed Solar Valuation Study.* Presented to the Main Public Service Utilities Commission. April 14, 2015.

Table 2-1 (Continued)

Avoided System Losses	Preventing energy lost over the transmission and distribution lines to get from centralized generation resources to load	.02-4.5 c/kWh[1]	1.3 c/kWh	2008-2015
Avoided Reserve Margins Cost	Contribution to reduced or deferred costs associated the utility's requirement to maintain a reserve margin of 13% to 17% of generating capacity	.2-.5 c/kWh[1]	.35c/kWh	2013-2015
Grid Reliability /Avoided Disruption Cost	The grid security attributable to potential to reducing outages by reducing congestion along the T&D network and increasing fuel diversity. Quantified typically as the value of avoided outages based on the total cost of power outages.	.02-14.40 c/kWh[1]	5.1 c/kWh	2012
Avoided Transmission and Distribution Capacity	Contribution to deferring the addition of transmission and distribution resources need to serve load pockets, far reaching resources, or elsewhere	.01-9.9 c/kWh[1]	2.5 c/kWh	2008-2013
DRIPE	The reduction or mitigation of market prices due to reductions in demand for capacity and energy as "capacity DRIPE" and "energy DRIPE," respectively.	.5-6c/kWh[1]	3.25 c/kWh	2013-2015
Avoided Environmental Compliance Costs	Marginal Cost of complying with existing environmental regulations	0.03-2.4 c/kWh[1]	1.1 c/kWh	2008-2015
Avoided Carbon Emissions	Avoided costs to mitigate CO_2 or equivalent emissions	2.2-2.5c/kWh[1]	2.35 c/kWh	2015
Fuel Hedge	Avoided costs to lock in future price of fuel as protection against price volatility	.03-3.7 c/kWh[1]	2 c/kWh	2008-2013

Table 2-1 (Continued)

Market Price Mitigation	Reduction in energy and capacity wholesale market prices due to lower demand	2.1-7.1 c/kWh[1]	3.8 c/kWh	2008-2012

Table 2-2-Recognized Environmental or Social Value Streams in VOS methodologies

Potential Environmental and Social Benefits	Description	Min- Max	Avera ge	Year Range
Avoided Carbon Impact Cost	Avoided costs associated with marginal reduction in carbon. These reduced costs are additional to current environmental regulation.	.8-1.5[4]	1.15 c/kWh	2015
Avoided Water Use	Avoided water use associated with thermoelectric water use.	.004c/kWh[5]	.004c/ kWh	2015
Avoided Common Pollutant Cost or Criteria Pollutant	Avoided costs associated with marginal reduction in emissions of SO_2, VOCs, NO_x, $PM_{2.5}$, PM_{10} and NH_3[6]. These reduced costs are additional to current environmental regulation.	.03-10 c/kWh.[7]	4.5 c/kWh	2011-2012

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4 Acadia 2015a; Acadia 2015b

5 Tennessee Valley Authority (2015) DG-IV Process.

6 SO_2 – Sulfur Dioxide; VOC – Volatile Organic Compound; NO_x – Nitrogen Oxide; $PM_{2.5}$ – Fine Particulate; PM_{10} – Particulate Matter; NH_3 – Ammonia;

7 Crossborder, 2012; Epstein, P., Buonocore, J., Eckerle, K. et al., *Full Cost Accounting for the Life Cycle of Coal*, 2011; Muller, N., Mendelsohn, R., Nordhaus, W., *Environmental Accounting for Pollution in the US Economy.* American Economic Review 101*,* Aug. 2011. pp. 1649 – 1675; National Research Council. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use,* 2010.

Table 2-2 (Continued)

Renewable Energy Credits	The value of utilizing the exported value of DGPV to sell Renewable Energy Credits.	.1 c/kWh[8]	.1 c/kWh	2015
Job Creation Benefits	Job impact based on enhanced tax revenues associated with the net job creation for solar vs conventional power resources.	1.1-4.1 c/kWh[9]	2.6 c/kWh	2012

Table 2-3 Potential Cost/Benefits in VOS Methodologies

Potential Costs/Benefits	Description	Min-Max	Average	Year Range
Additional Transmission and Distribution Investments	Additional costs to the utility to integrate solar pv to the existing grid in terms off added T&D lines for utility-scale solar or upgrades to existing lines for DG solar	-(2.2-.01) c/kWH[10]	-1 c/kWh	2012-2013

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8 TVA, 2015

9 CPR, NJ/PN, 2012

10 Xcel, 2013; CPR (NJ/PN) 2012

Table 2-3 (Continued)

Integration / Interconnection	Increased costs for regulation and operating of current reserves to manage, integrate and interconnect variable DG resources	-(.9 -.1 to) c/kWh[11]	-1.3 c/kWh	2014
Additional Reserve Requirements	Additional investments necessary to acquire reserve requirements necessary to supplement wholesale power	-1.5-.5 c/kWh[12]	0 c/kWh	2013
Ancillary Services	Reactive supply and voltage control; frequency regulation; energy imbalance; and scheduling.	-1.8 -.08 c/kWh[13]	-.5 c/kWh	2009-2013

As we can see, there are multiple components that can be included in a VOS methodology. And there is significant range in estimates. All valuation is a function of the local system and the methods used and the assumptions made in valuation process. For example, the wide range in benefits from avoided generation capacity will be determined by how much generation capacity the presiding utility plans to procure over the lifetime of the solar system. If there is little need for additional generation capacity, DGPV many receive little capacity value. Every utility has different variable costs (fuel and purchased power), fixed costs (generation

[11] Lu, S., Warwick, M., Samaan, N., Fuller, J., Meng, D., Diao, R., & Vyakaranam, B. (2014). Duke Energy Photovoltaic Integration Study: Carolinas Service Areas. *Pacific Northwest National Laboratory*.

[12] Crossborder (NC) 2013

[13] Crossborder (AZ), 2013; Crossborder (CA), 2013; LBNL, 2012; E3, 2012; NREL 2008; APS, 2009

capacity, transmission, and distribution), line losses (distribution and transmission), different demand profiles, different restrictions regarding ancillary services (to maintain grid reliability), and different policy objectives such as the reductions of carbon emissions. In terms of the utility avoided costs, utilities with high fuel costs, immediate capacity needs, and heavy congestion on the distribution system will likely see a higher value for DGPV compared to systems with low fuel costs and no capacity needs. Similarly, the degree to which environmental and social components are recognized in the VOS methodology, can greatly impact the overall value of the resource. In states with strong SREC markets or carbon emissions policies, solar has an additional market value as compared to states or jurisdictions that do not recognize the economic impacts of climate change or emission damages.

2.5.1 Methods impacting a VOS methodology

In addition to which components are assessed in a VOS methodology, the modeling assumptions, the modeling framework, and sources of cost information will greatly shape the result. While in theory, every component is variable to methodological assumptions, we touch on five input assumptions that can greatly impact both the valuation process and ultimately the VOST. These components include:

- The discount rate
- The system life or contract length used to evaluate the value of DGPV
- Financial forecasts on the cost of fuel that will be displaced by DGPV
- Effective Load Carrying Capability (ELCC) attributed to DGPV.
- The amount of DGPV on the system

The discount rate is the rate used to depreciate the future benefits and the costs of DGPV into an equivalent present value, given in real dollars. The discount rate functions as a parameter to inform an analysis on the long-term impacts of a policy. The discount rate can reflect the importance of future benefits, attitudes towards risk, uncertainty about future impacts, and even the potential inequality between members of current and future generations (Lind, 1982; Dasgupta, 2008). Which discount rate a VOS methodology employs may be uniform across all components our change based on the participating stakeholders' concern. Generally speaking, low discount rates will discount the future costs and savings less than compared to higher discount rates. From a policy perspective, the social discount rate influences the degree of concern society displays about a policy's effects on individuals in the future (Kelleher, 2012). For a VOS methodology, the discount rate chosen impacts every single component and the resulting VOST.

The system life or contract length used to evaluate the value of DGPV can also impact the overall value attributed to DGPV. Typically, most VOS studies assume a 20 or 25-year system life for DGPV. The contract length, in conjunction with the discount rate can either increase the value attributed to DGPV, depending on the utility's current and future system needs. Ultimately the contract length is another reflection of risk. Longer contract lengths are inherently riskier to the utility but provide more certainty to the customer. Additionally, whether the VOS framework chooses to levelize the analysis or use annual values will impact the results.

Financial forecasts on the cost of fuel that will be displaced by DGPV will greatly impact the energy value attributed to DGPV. For most utilities, DGPV will displace gas-fired generation resources and thus estimates on future natural gas prices will impact the value of DGPV towards avoiding fuel costs. In many VOS methodologies, additional components such as ancillary service, capacity and spinning reserves, as well as fuel hedging are all tied to the forecast of future fuel prices.

Effective Load Carrying Capacity (ELCC) is a metric that captures a generating resource's contribution to meeting a utility's capacity requirement. ELCC and similar concepts are generally applied to intermittent resources to determine what percentage of their installed capacity can receive credit towards reducing capacity needs (Norris, 2014). The ELCC is typically calculated against the utility's peak demand period.

In a VOS Methodology, the ELCC is used to adjust the calculated economic value of the following components to reflect the intermittency of DGPV (Norris, 2014):

- Avoided Generation Capacity Cost and O&M
- Avoided Reserve Capacity Cost
- Avoided Transmission Capacity Cost

Finally, the orientation of the DGPV systems and the amount of modeled DGPV on the system also impacts the value attributed to the resource and can shape other methodological components including the ELCC and potential integration costs. In any VOS methodology, stakeholders must establish a reasonable estimate for DGPV growth so as not to attribute benefits or costs that will not be realistically realized. Also, the difference in production from a south or west-facing system can vary significantly. When available stakeholders should utilize empirical estimates from multiple, variant oriented systems.

2.6 A Value of Solar Case Study in Georgia

2.6.1 Background on DGPV in Georgia

Georgia is one of the few states in the country that does not have either a renewable portfolio standard or a net metering program. Accordingly, since 2001, the residential solar market has grown minimally. From 2007-2016, only 754 homes installed distributed solar in the entire state. The primary in utility in Georgia, Georgia Power, does offer minor compensation for exported power to customers, but maintains that NEM will result in upward pressure on non-solar customer rates.

The Georgia Cogeneration and Distributed Generation Act governs distributed solar PV capacity additions in the service territories of Georgia's utility monopolies, including Georgia Power Company. The Act requires utilities to "make either bidirectional metering or single directional metering available to customer generators," depending on how the customer's facility is connected to the grid. For distributed generation (DG) facilities connected on the customer's side of the meter, energy flow must "measure the electricity produced or consumed during the billing period," with a credit given to customers for excess generation. This credit for excess kilowatt-hours (kWh) must be compensated at an agreed to rate as filed with the Commission.

Since 2001, Georgia Power has adopted three distributed solar initiatives – the Renewable & Non-Renewable Tariff (RNR), Solar Purchase Tariffs (SP), and the Advanced Solar Initiative (ASI). RNR, which was Georgia Power's way of implementing the Act, is structured as an avoided cost tariff, with a slightly higher energy rate than the utility's traditional avoided cost to account for solar energy's unique production profile. Under the RNR program, participants retain the right to consume on-site generation and to export any excess generation to the grid. This is often referred to as "behind-the-meter" generation. RNR provides participants with an export rate that is essentially equal to Georgia Power's avoided cost of fuel. This rate is variable but averages around \$0.04/kWh. In contrast, the SP programs have been structured as buy all/sell all arrangements funded through voluntary customer subscriptions to the Green Energy program. The current SP program provides a fixed rate of \$0.17/kWh to eligible participants. The ASI program is the most recent to include DG offerings. It too is structured as a buy all/sell all program. In its initial phase, Georgia Power provided a fixed rate of \$0.13/kWh to eligible DG solar participants with contract terms of 20 years.[14] Under the current phase of the program, the Company is offering fixed rates ranging from \$0.089 to \$0.114/kWh depending on the contract term, which can range from 15 to 35 years, for projects under 500 kW.

Despite these programs, the residential DG market in Georgia has seen little growth in the past ten years. In part this is due to the way Georgia's solar policies are structured. The ASI programs have provided limited capacity and have been structured to encourage large-scale commercial and utility-scale development. As for the SP program, as of 2014, it has just 193 contracted solar projects, with a wait list currently in effect. The result is that a large majority of Georgia Power customers interested in DG solar are left with the RNR program as their only option. At present, the RNR program provides only minimal compensation for solar exports and does not provide the option of fixed, long-term contracts.

2.6.2 Methods

As outlined, the value of customer-sited DGPV electricity is ultimately a function of the value streams regulators deem appropriate. The values are shaped by the local electricity

[14] The most recent order for ASI Prime for systems under 500 kW projects ranges from 8.9 c to 11.4 c depending on contract term, with contract lengths of 15, 20, 25, 30 and 35 years. However, these values have yet to be adopted.

demand, local generation, electricity markets, transmission and distribution systems, the potential impacts DGPV may have on the environment, society, and ultimately the valuation methods employed. The purpose of our analysis is to determine a value of customer-sited DGPV with publicly-available data and illustrate how the estimates of a VOST can range dramatically based on differences in the valuation methods and the included value streams. For my analysis, I include the following value streams: avoided utility costs, costs to the utility, environmental benefits, and societal benefits. For avoided utility costs we include: avoided energy, avoided capacity, avoided ancillary services, and avoided transmission and distribution costs. For utility costs, I include integration costs associated with the operations and maintenance of the distribution system. For environmental and societal benefits, I include avoided carbon emissions, avoided common pollutants, and the value of Solar Renewable Energy Credits. Given that my analysis is limited to public data there are a number of value streams that we cannot estimate, specifically the benefits that DGPV may bring to the transmission and distribution system.

For my analysis of a VOST we estimate values over the lifetime of GPC current solar contracts, which is 20 years. Accordingly, I calculate the benefits and costs of DG over a 20-year period in order to capture fully the value of these long-term resources. I model all energy components in the analysis under three different discount rates- 3%,5%, and 8%, and all environmental components are modeled at a 3 % discount rate. The 3% rate was assumed based on precedence set by the Office of Management and Budget for program cost-benefit analysis and public investment on programs that have societal implications (OMB,2016). The choice to model the energy components under different discount rates are done so in order to illustrate how the discount rate can greatly impact the valuation process. I also conducted sensitivity analysis for our estimates of avoided energy costs and avoided capacity costs as these two variables, and how they are estimated, greatly impact many of the other components. Additionally, while I estimate our values over 20 years, our results illustrate how a longer or shorter time period can impact the final estimates of a VOST. To calculate the components for a VOST the following data are needed for each hour of the selected load analysis period (Minnesota Department of Commerce, 2014):

- Hourly Net Generation Load – Total net generation and purchased power required to satisfy the utility's customer load.
- Hourly Solar Fleet Production – Total generation from solar systems across the utility's service territory.

Again, neither of these data series are readily available from public sources. Therefore, hourly data was approximated or simulated using the methods described below.

Section 2.5.3 Determining an Hourly Generation Profile for GPC

To determine an hourly generation profile, I combine information about the hourly demand, GPC's generation portfolio and historical generation deployment. We utilize data from the Environmental Protection Agency's AMPD database, the Energy Information Administration Forms 923 and 860, SEC Filing 10-K, FERC Form 714, and the Environmental Protection Agency National Emissions Inventory.

We use total capacity, capacity value, and total generation information about each power plant, by fuel-type in GPC territory to determine whether the plant is primarily a baseload plant or peaking plant. In general, very large plants tend to be baseload, as do coal and nuclear plants.

Plants with higher capacity factors are also likely being used to meet baseload demands. Power plants are then grouped by fuel-type and whether they are baseload or peaking resources. For example, there might be five baseload bituminous coal plants of 500MW capacity each, so the value calculated would be 2500MW of baseload bituminous coal. Then the total capacity from these plants are grouped together and weighted by the average capacity factor for both baseload and peak capacity. These calculations provide estimates of the total weighted average baseload and peak capacity available to meet demand in any given hour.

Table 2-4 Variables used to determine baseload, peak, and purchase power for GPC

Fuel Type	Baseload	Peak	Capacity (MW)	Average Capacity Factor
Bit Coal	x		6533.5	27%
Natural Gas	x		4073.8	58%
Nuclear	x		1933.3	95%
Subbit Coal	x		794.2	67%
Baseload Coal Subtotal	x		7327.7	33%
Distillate Fuel Oil		x	965	0.02%
Natural Gas		x	972.05	1%
Residual Fuel Oil		x	0	0%
Solar		x	1.1	15%
Water		x	1186	14%
Baseload Sum			15283.5	
Peak Sum			3124.15	
Total Generation Baseload (MWh)	59,740,934			
Total Generation Peak (MWh)	3,513,776			
Total Purchased Power (MWh)	26,968,315			

To determine an hourly demand curve, I utilize historical average hourly demand data by month reported to FERC. FERC Form 714 provides hourly demand data for GPC through 2015. Figure 2.2 Provides the average hourly demand profiles for GPC in 2015.

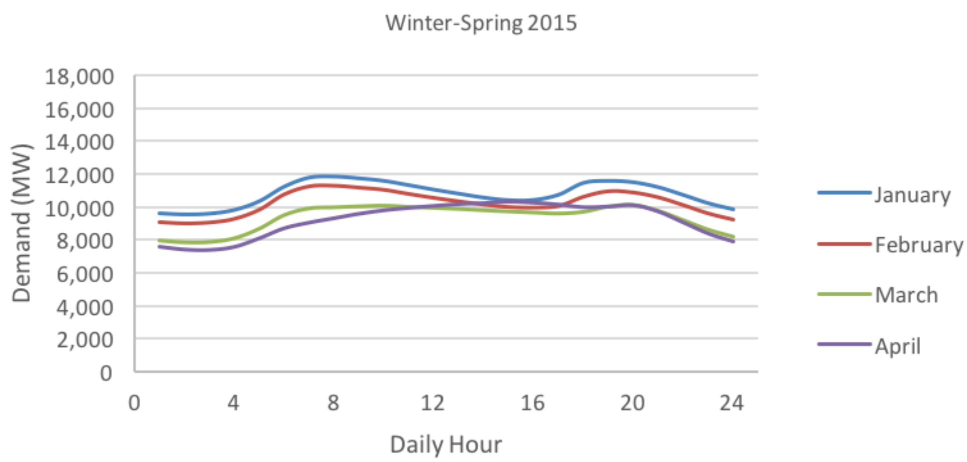

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Figure 2-2a Average Hourly Demand profiles for GPC, 2015

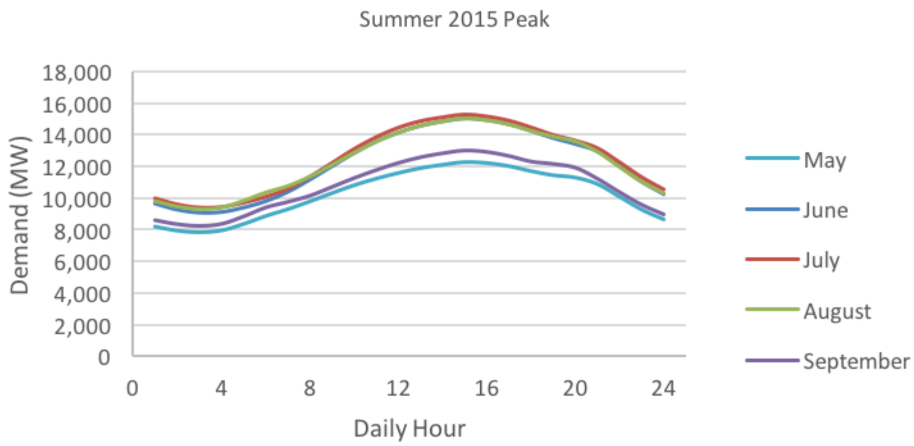

Figure 2-3b Average Hourly Demand profiles for GPC, 2015

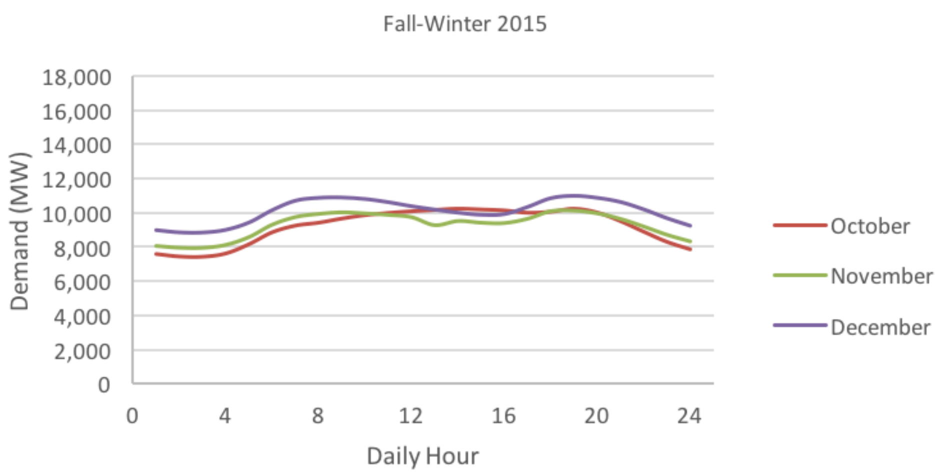

Figure 2-4c Average Hourly Demand profiles for GPC, 2015

I then compare the average hourly demand profile for each month to the weighted average baseload and peak capacity available. Each average demand hour is first met by baseload resources, then peak resources, then purchased resources. If demand exceeds the sum of the average baseload and peak capacity, I assume power purchases are made until demand is met. Figure 2.3 shows how purchase power varies throughout the year, based on 2015 data. For the data used to estimate demand, baseload, peak, and purchased power see the Appendix.

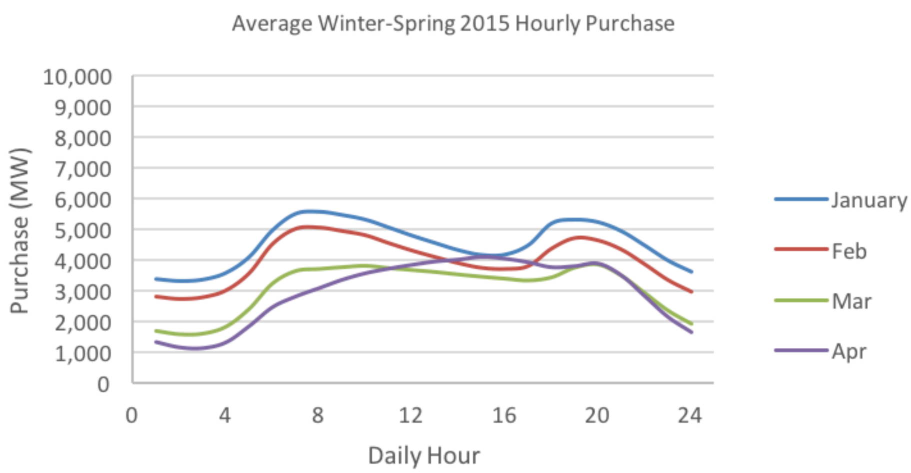

Figure 2-3a Purchase-power profiles for GPC

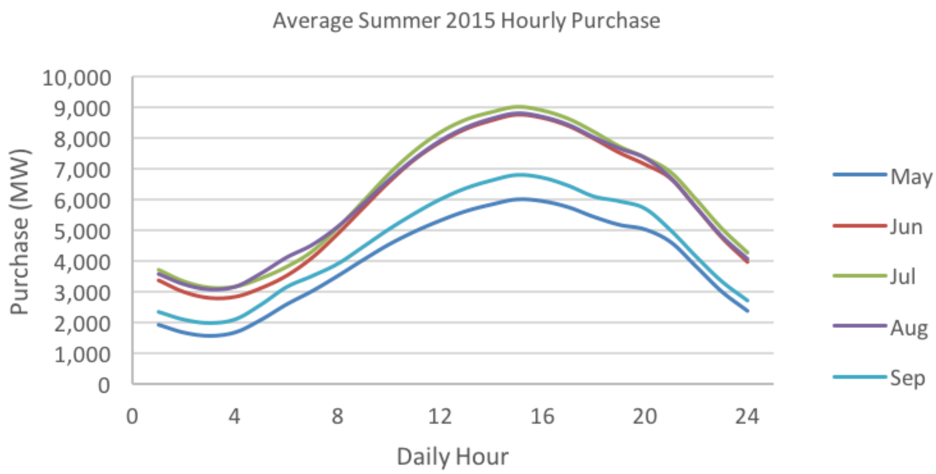

Figure 2-3b Purchase-power profiles for GPC

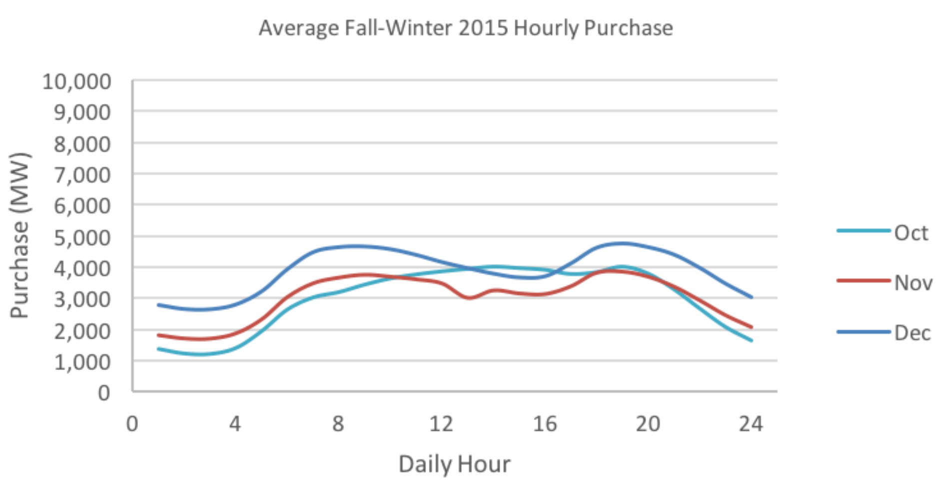

Figure 2-5c Purchase-power profiles for GPC

2.6.3 Determining a Distributed Solar Generation Profile

The aggregate production profile of distributed solar generation is relevant for the determination of DGPV's energy and capacity value, of which my estimates of transmission and distribution as well as ancillary services are produced.

To approximate both aggregate and hourly production of DGPV in Georgia I utilized data from Southface Energy Institute's Energy Dashboard Database (2016). We estimate a total capacity of 702 MWs of roof-top DGPV. I utilize NREL's PVWatts calculator to generate the hourly generation profile. Given that the majority of the rooftop DGPV is located in Atlanta, GA, I chose to analyze our production in Atlanta, Georgia, using a 16% capacity factor, assuming system losses of 14%, an inverter efficiency of 96%, a 30-year useful life, and a DC to AC Size Ration of 1.1. From PVWatts, we calculated that for every kW of distributed residential solar, the system generates an average of 1,456 kWh/year, resulting in a first-year annual output of 1,022 MWhs. I assume a degradation rate of .5% over a thirty-year system life, resulting in a total system output of 18,852 MWh.

2.7 Model Components

Determining the value of any energy resource, whether distributed or conventional, is complex and requires a thorough analysis of the electricity system it supports. Distributed solar energy adds an extra layer of analysis because there are additional values associated with distributed solar energy, as compared to conventional power plants. Some of these values include: avoided capital investments in conventional power generating units; reductions in fuel costs during high-demand periods; emissions-free generation; and reductions in water use during high-demand periods. In this section, I provide an overview of the multiple components included in determining the value of solar for Georgia Power's system and how these values are evaluated marginally, in c/kWh.

2.7.1 Avoided Energy

Solar energy has zero fuel costs, as such it provides a benefit to the utility compared to generation sources with fuel costs. In my analysis, we define Avoided Energy costs as the avoided fuel costs incurred by a utility by utilizing solar energy. According to GPC's 2016 IRP, peak energy will be met largely through purchased power or through gas-fired resources. In my analysis, we compare our baseline generation profile and our baseline solar profile to determine the proportion of hours met by purchased power and the proportion of hours met through peak generation resources. Under current penetration levels, generation from distributed solar primarily displaces purchased power during peak hours, as GPC typically purchases power for its top peak hour needs, and displaces power from gas-powered resources in non-peak hours.[15] To determine the value of avoided energy I assess the average value of purchased fuel costs against the average energy costs of gas-fired generation resources. To estimate avoided energy costs, I first develop a long-term forecast of GPC's cost of natural gas. This forecast uses current (February 1, 2016) forward gas price data from the Southeast Reliability Corporation East and Southeast markets. Figure 2.4 compares the natural gas cost estimates. Because our forecast is based on forward market natural gas prices, it represents a potentially volatile variable cost that

[15] GPC decision to purchase power is dependent on a comparison between the cost of purchased power and GPC's cost to ramp dispatchable units to meet demand. GPC's units generally dispatch at a lower cost than their purchasing affiliates (GPC, Annual Report, 2015)

GPC could fix for the next 30 years. This captures the fuel price hedging benefit of distributed solar.

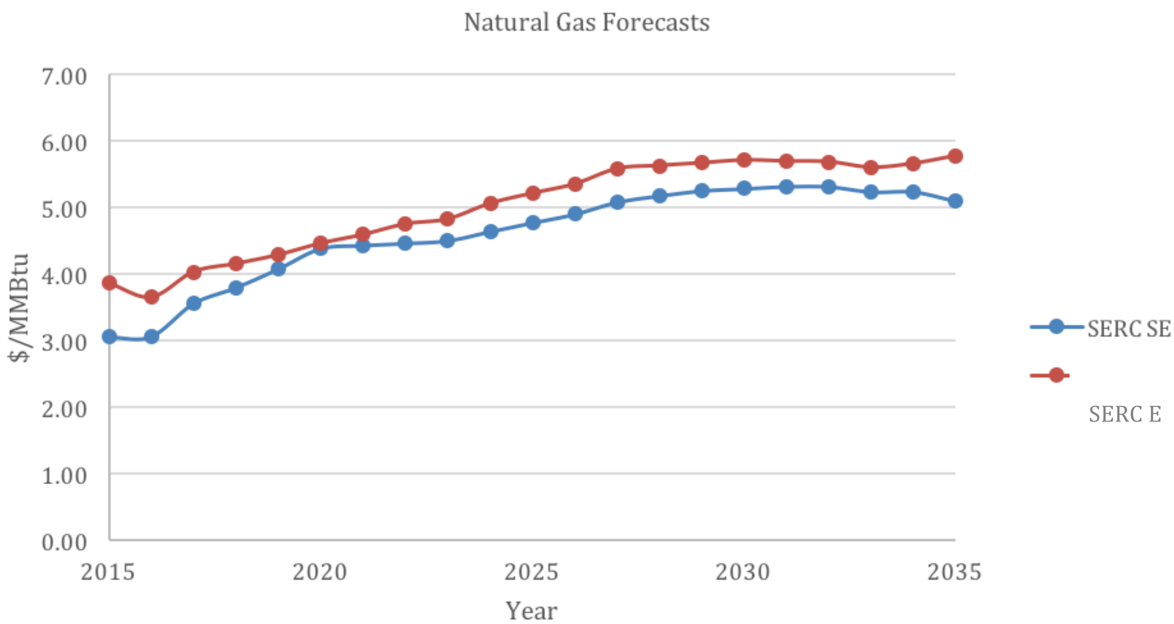

Figure 2-6 Projected Natural Gas Prices for the SERC Region

I assume that distributed solar avoids generation from natural gas combustion turbines (NGCTs) with a heat rate of 10850 BTU/kWh (EIAa, 2016) and use our gas price forecast as the fuel costs for these avoided resources. According to GPC 2016 IRP, the only potential generation resource slated for installment over the next ten years is NGCTs (GPC, 2016).[16] GPC's average fuel costs for purchased generation over the past four years is 5.4 c/kWh. How these hours are determined is subject to Georgia Power's classification of off-peak generation. Georgia Power

[16] GPC does not specify when these plants will be installed just that NGCTs are proposed generation source to meet capacity.

defines peak hours as occurring from 2pm – 7pm on weekdays, June through September, excluding holidays.

I match the average marginal prices of power during peak hours (2pm – 7pm on weekdays, June- September) and off-peak hours and weight the value of solar generation accordingly. I estimate that 38% of distributed solar produces during peak hours and 62% produces in non-peak hours. We calculate the avoided energy costs, *AE*, as:

Equation 2.1 Avoided Energy

$$AE = \frac{\sum_{m=1}^{m} Np^{*}p_g + Op^{*}p_p}{\gamma^i}$$

m=total number of hours, 8760

Np= % non-peak hours corresponding with solar generation profile

Op= %peak hours corresponding with solar generation profile

p_g =30-year, levelized price of natural gas

p_p =historical purchased-power price

$$\gamma^i \equiv \frac{1}{1+r} = discount\ rate$$

Table 2.5 summarizes the resulting 30-year levelized avoided energy costs for distributed solar in GPC's service territory under various discount rates.

Table 2-5 Avoided Energy Costs

		June-September	October-May	
Discount Rate	Levelized Energy Values	11%	89%	Weighted Annual c/kWh
3%	Purchase Power (June-September) and Gas Prices (October-May)	4.4	4.1	*4.2*
5%	Purchase Power (June-September) and Gas Prices (October-May)	3.8	3.5	*3.5*
8%	Purchase Power (June-September) and Gas Prices (October-May)	3.2	3.0	*3.0*

Recognizing that our estimates of avoided energy are sensitive to forecasts of natural gas prices, we examine the impacts under a 25% and 50% increase in natural gas prices over the next 30 years. Figure 2.5 and Table 2.6. presents the results of our sensitivity analysis. Under a 3% discount rate, assuming a 50% increase in natural gas prices, the value that DGPV could provide in terms of avoided energy costs can range as high as 5.95 c/kWh.

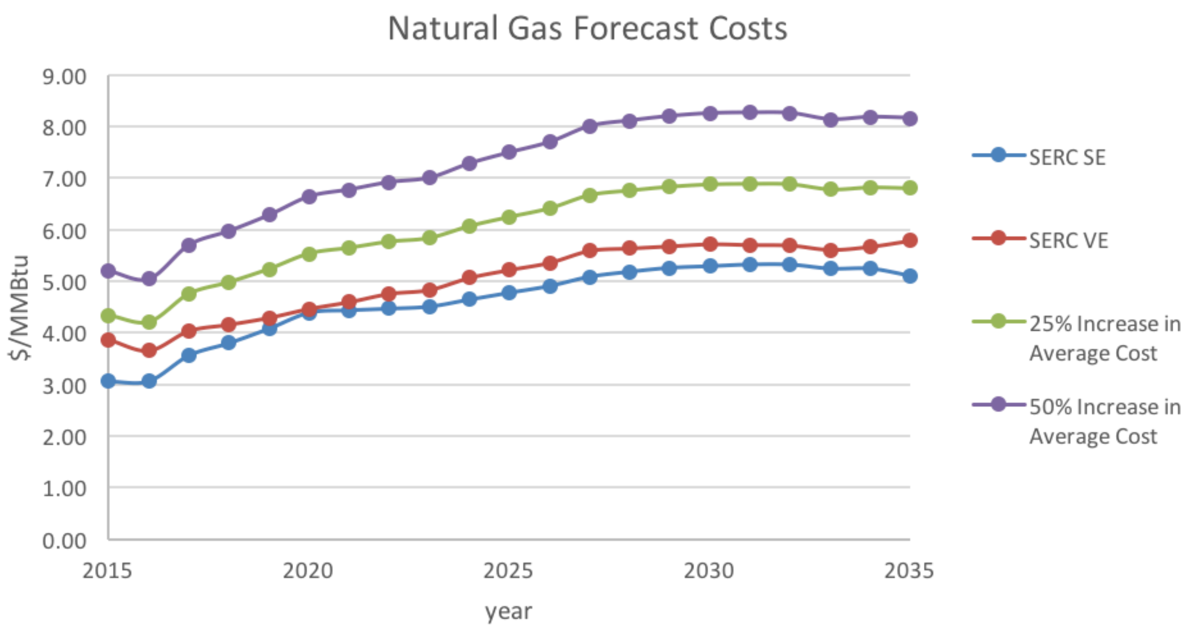

Figure 2-7 Estimated Increase in Natural Gas Prices

Table 2-6 Avoided Energy Cost under increase in Projected Natural Gas Costs

		June-September	October-May			
Discount Rate	Levelized Energy Values	11%	89%	Weighted Annual c/kWh	Under 25% increase in NG prices	Under 50% increase in NG prices
3%	Purchase Power (June-September) and Gas Prices (October-May)	4.4	4.1	*4.2*	*5.1*	*5.95*
5%	Purchase Power (June-September) and Gas Prices (October-May)	3.8	3.5	*3.5*	*4.4*	*5.09*
8%	Purchase Power (June-September) and Gas Prices (October-May)	3.2	3.0	*3.0*	*3.7*	*4.35*

2.7.2 System Capacity (Capacity & Variable O&M)

Distributed solar has the unique value of scalability and quick development, and at large levels of penetration can avoid the need for supply-side resources and increased capacity. To determine a value for displaced capacity I examined total new capacity plans for GPC. GPC has no short-term peaking capacity resources slated for construction over the next five years (GPC, 2016). To calculate the capacity value of distributed solar, a conservative estimate for the levelized fixed cost of natural gas combustion turbines, using the current average capacity factors and operations and maintenance factors for natural gas combustion turbines currently operated in the region. I assumed an overnight capital cost of 910 $/kW (EIA, 2016b) with a fixed operations and maintenance cost of $7.21 $/kW (EIA, 2016b) and a variable operations and maintenance of 15.81$/MWh. The levelized NGCT fixed costs are multiplied by an effective load carrying capacity (ELCC) of PV generation. Currently there are no reports documenting the empirical ELCC for solar in Georgia. However, our comparison between our baseline GPC hourly generation profile and DGPV profile revealed that under peak hours of GPC, from June through September for the hours of 2:00 PM through 7:00 PM, that on average distributed solar has a 50% ELCC. Figure 2.6 presents the average hourly baseline generation profile for GPC against the average daily DGPV profile in August.

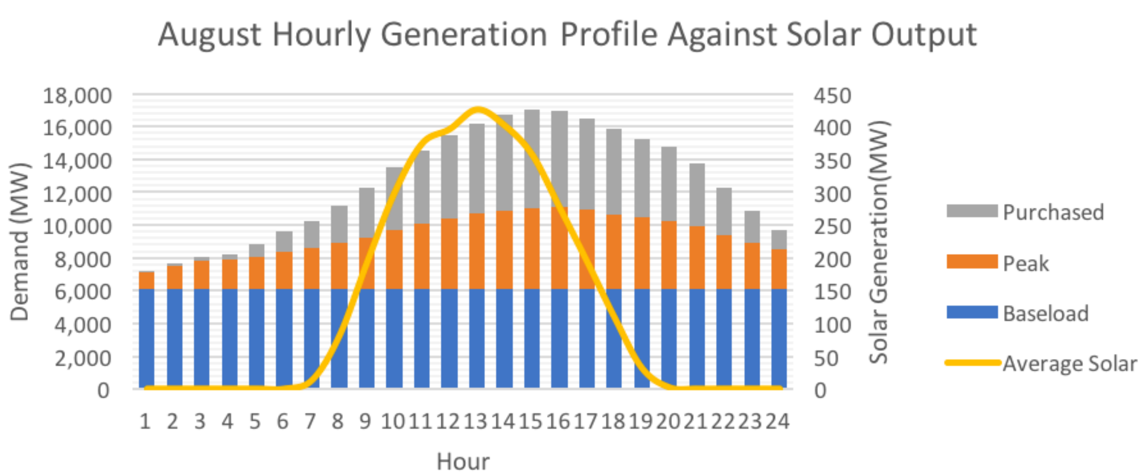

Figure 2-8 Average Generation of DGPV under Peak GPC Hours in August

Table 2-7 Estimated Avoided Capacity Costs

	LCOE Component			
	Overnight Capital ($/kw)	664		
	Fixed O&M ($/kw)	7.04		
	Variable O&M ($/kwh)	.01		
Discount Rate	LCOE of NGCT		ELCC	Levelized c/kWh
3%	LCOE of NGCT	7.7	50%	*3.85*
5%	LCOE of NGCT	9.1	50%	*4.5*
8%	LCOE of NGCT	11.6	50%	*5.8*

Recognizing that our system capacity values are heavily determined by the ELCC, I follow Norris (2014) and run sensitivity analysis assuming a 25% ELCC and a 5% ELCC. Table 2.8 presents the results of our sensitivity analysis. Under an 8% discount rate and 5% ELCC our estimates for the value that DGPV can provide in terms of avoided system capacity costs can drop to .39c/kWh.

Table 2-8 Avoided Capacity Costs under decreased in ELCC

Discount Rate	LCOE of NGCT		ELCC	Levelized c/kWh	Levelized c/kWh (under a 25% ELCC)	Levelized c/kWh (under a 5% ELCC)
3%	LCOE of NGCT	7.7	50%	*3.85*	*1.9*	*0.39*
5%	LCOE of NGCT	9.1	50%	*4.5*	*2.3*	*.45*
8%	LCOE of NGCT	11.6	50%	*5.8*	*2.9*	*.58*

2.7.3 Ancillary Services and Capacity Reserves

SERC reliability standards require control area operators to maintain operating reserves (spinning and non-spinning) of 2000 MW (NERC, 2015). When assessed against GPC total portfolio of 15,454 MWs, this accounts for 13% of the load served by thermal generation. Load reductions from DG will reduce GPC's need for operating reserves. Additionally, GPC has maintained a capacity reserve margin of 14.5% (GPC, 2016). This means that each kW reduction in GPC's peak demand from DG will reduce the utility's capacity requirements by 1.145 kW. To estimate avoided ancillary service and capacity reserve requirements I calculate 13% of the avoided energy costs and 14.5% of the avoided generation capacity costs.

Equation 2.2 Avoided Ancillary Costs

$$A = \sum 13\% \cdot AE + 14.5\% \cdot AG$$

$AE = avoided\ energy\ costs$

$AG = avoided\ generation\ costs$

Table 2-9-Avoided Ancillary Services

		Avoided Energy	Avoided Generation Capacity	
Discount Rate	Avoided Costs	13%	14.5%	Levelized c/kWh
3%	Ancillary Services + Capacity Reserve	*4.2*	*3.8*	*1.09*
5%	Ancillary Services + Capacity Reserve	*3.5*	*4.5*	*1.1*
8%	Ancillary Services + Capacity Reserve	*3*	5.8	*1.2*

Given that my estimates of avoided ancillary costs are tied to avoided energy and capacity costs, I run our estimates against the sensitivity analysis for both variables. Table 2.9 provides the range of estimates for avoided ancillary costs based on variations in our estimates of avoided energy and avoided generation capacity. The range of value for avoided ancillary services is .44c/kWh-1.6c/kWh. These estimates are in line with the literature (See Table 2.1.).

Table 2-10-Avoided Ancillary Services under Sensitivity Analysis

Discount Rate	Avoided Costs	Levelized c/kWh	25% increase in NG	50% increase in NG	25% ICE	5% ICE	25% increase + 25% ICE	25% increase + 5% ICE	50% increase + 25% ICE	50% increase + 5% ICE
3%	Ancillary Services + Capacity Reserve	*1.3*	*1.2*	*1.3*	*0.82*	*0.61*	*.94*	*0.72*	*1.1*	*0.82*
5%	Ancillary Services + Capacity Reserve	*1.1*	*1.2*	*1.3*	*0.788*	*0.52*	*0.9*	*0.64*	*1*	*0.73*
8%	Ancillary Services + Capacity Reserve	*.94*	*1.3*	*1.4*	*0.81*	*0.7*	*0.9*	*0.57*	*.99*	*0.64*

2.7.4 Transmission System & Distribution Avoided Losses and Potential Integration Costs

The impact of DGPV on the transmission and distribution system is at the center of many policy and regulatory debates regarding NEM and VOS. Utilities argue that DGPV incurs a cost to the T&D system because it is a variable resource that, if not controlled, can result in additional management and potentially capital costs to the utility (Ackerman and Martini, 2013). These costs are often referred to as 'integration costs.' However, DGPV has also been proven to provide direct value to the management of the distribution system in the form of load relief and voltage control. Additionally, given that DG solar primarily serves on-site loads, it has the benefit of reducing loads on the transmission and distribution system and avoiding capacity costs, including lines or infrastructure. However, determining the exact value of T&D impacts is a function of the amount of distributed generation, the distance of generating source to end-use loads, the capacity of the distribution load, and the dynamics of load on the local substation. To truly understand the full costs and benefits of DGPV to the T&D system, power flow modeling of the deployed resources would be needed, which is outside the scope of this study. Instead, I focused on two components; average avoided line losses, integration costs, and average T&D operation costs.

2.7.5 Average Line Losses

Because DGPV is located at load, as a generation resource it does not require the use of the transmission system and therefore reduces line losses. The benefit that distributed solar brings to the grid's transmission loss can range greatly. Other VOS studies have shown a range from 0.2 c/kWh to 9 c/kWh (EPRI, 2015). The higher range is often reflective of an optimized placement of load, i.e placing distributed solar in areas where it can be load supporting. I estimate transmission impacts utilizing publicly available, actual observed loss impacts, positive or negative. Avoided T&D costs are calculated using average line losses of 7%. Average line losses of power lines in Georgia are reported by the EIA. Transmission line losses are not associated with a specific technology but rather with the amount of power on the system at any given time of the day. Because this analysis is modeling a behind-the-meter generation scenario, it is assumed that all DG solar generation that is not used on-site will be exported to the nearest neighboring demand site. As such, the solar transmission loss is effectively zero, meaning that the value of line losses for DG solar equates to marginal value of line losses for Georgia. To estimate the avoided costs associated with line losses, *LL,* I calculate 7% of the avoided energy costs and 7% of the avoided generation capacity and avoided energy costs. Table 2.11 provides my estimates.

Equation 2.3Line Losses

$$LL = \sum 7\% \cdot AE, AG$$

Table 2-11-Estimates of Avoided Costs due to reduced Line Losses

		Avoided Energy	Avoided Generation Capacity	
Discount Rate	Avoided Costs	7%	7%	Levelized c/kWh
3%	Line Losses	*4.2*	*3.85*	*0.56*
5%	Line Losses	*3.5*	*4.5*	*0.56*
8%	Line Losses	*3*	*5.8*	*0.61*

Again, recognizing that my estimates of avoided line losses are tied to avoided energy and capacity costs, we run our estimates against the sensitivity analysis for both variables. Table 2.12 provides the range of estimates for line losses costs based on variations in our estimates of avoided energy and avoided generation capacity. The range of value of for line losses is

.24c/kWh-.83c/kWh. These estimates are below the average for found in the literature (see Table 1) but still within range.

Table 2-12-Avoided Costs due to reduced Line Losses under Sensitivity Analysis

Discount Rate	Avoided Costs	Levelized c/kWh	25% increase in NG	50% increase in NG	25% ICE	5% ICE	25% increase + 25% ICE	25% increase + 5% ICE	50% increase + 25% ICE	50% increase + 5% ICE
3%	Line Losses	*0.56*	*0.62*	*0.69*	*0.42*	*0.32*	*0.49*	*0.39*	*0.55*	*0.44*
5%	Line Losses	*0.56*	*0.62*	*0.67*	*0.41*	*0.28*	*0.48*	*0.34*	*0.51*	*0.39*
8%	Line Losses	*0.61*	*0.65*	*0.71*	*0.41*	*0.25*	*0.46*	*0.29*	*0.5*	*0.34*

2.7.6 Integration Costs

DGPV's impact on the management and operations of the T&D system and the potential the increase in operating costs due to uncertainty and variability in DGPV output (primarily balancing load flows and managing potential voltage fluctuations) is commonly referred to as the 'integration costs' of solar. These integration costs are also a major component of utilities' arguments against retail-rate NEM, claiming that DGPV incurs a cost on the system that is not accounted for and therefore must be subsidized by other, non-solar customers. While very few utilities have performed the necessary advanced power flow modeling necessary to assess the integration costs of solar, there have been dozens of attempts to assess a fixed charge to DGPV customers' rates in order to recoup any integration costs (NC Clean Energy Technology Center, 2016).

It should be noted that DGPV has been shown to provide value to the distribution system (Cohen, 2015), and that research has shown that in low penetration levels, DGPV's impact on T&D is minimal. Without the capacity of power flow modeling, we assume a static value for the potential costs that DGPV could incur on the T&D. Using reported GPC expenditure filings in FERC Form 1, I estimate the average combined T&D operations and maintenance expenses from 2012-2015 per MWh of generation on the GPC.

Equation 2.4 Transmission and Distribution

$$\sum_{n}^{i}(T_i + D_i)/G_i \cdot \gamma^i$$

where

Ti= O&M cost of the transmission system in year i

Di= O&M cost of the distribution system in year i

Gi=total generation from the baseline portfolio in year i

The result was an estimated cost of $.42 c/kWh. To put this cost into perspective with other fixed charges that have been proposed throughout the country; if every kW of solar produces 1,145 kWh annually and the average residential DGPV system is 4 kW, the integration costs associated with an individual DGPV system can be estimated at $24 a year, or $2 a month. In contrast, many utilities have proposed fixed fees ranging from $12-$40 a month, in Nevada, and as high as $100 a month, Appalachian Power, to account for the integration costs of solar (Main, 2014). We discounted this cost accordingly over 30 years under each discount rate but also recognize that this number can go up or down according to penetration rates of solar. However, in order to truly gain insight on the potential integration costs of DGPV, advanced power flow modeling is necessary- which is outside the scope of this research. My analysis here is by no means an acceptable determinant for calculating these highly complex questions. If anything, my analysis serves to illustrate how rather cursory calculations can be used to satisfy what is ultimately rigorous engineering in a VOS methodology.

Table 2-13-Estimated Integration Costs

Discount Rate	Cost of DGPV	Levelized c/kWh
3%	Integration	-0.22
5%	Integration	-0.15
8%	Integration	-0.08

2.7.7 Common Pollutant Impacts

Distributed solar is emission free and when integrated into Georgia Power's system results in reduced emissions of SO_2, VOCs, NO_x, $PM_{2.5}$, PM_{10} and NH_3[17]. A substantial body of research has gone into determining cost impacts of these common pollutants. These costs are external to the costs borne by Georgia Power to achieve the level of compliance required. The externality costs associated with these emissions are primarily related to health effects and monetary damages associated with public exposure to common air pollutants. Externality costs are chiefly driven by adverse effects on human health, but also include some other values like reduced yields of agricultural crops and timber and damages due to lost recreational services.

To determine the value of reduced common pollutants, I utilize the Air Pollution Emission Experiments and Policy (AP2) model (Muller and Mendhelsohn, 2007), coupled with emissions data from EPA's AMPD database as well as the National Emissions Inventory, and integrate the outputs into our baseline generation profile. The AP2 model provides estimates of damage impacts in $/ton. This was converted into a rate of tons/MWH for each generating unit on the GPC based on gross generation data provided by the AMPD database and the EPA's National Emissions Inventory Database. These estimates were then assigned as a marginal emission impact for SOx, NOx, VOC, PM 2.5, and NH3 for each generating unit in baseline year, 2015.

Equation 2.5 Marginal Impact Common Pollutants

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[17] SO_2 – Sulfur Dioxide; VOC – Volatile Organic Compound; NO_x – Nitrogen Oxide; $PM_{2.5}$ – Fine Particulate; PM_{10} – Particulate Matter; NH_3 – Ammonia

$$CP_{g,n,i} = \frac{E_{n,i} * P_{n,i}}{G_{g,i}}$$

$E_{n,i}$ = Emissions in tons, per pollutant *n* in year *i*

$P_{n,i}$ = Cost in $, per pollutant *n* in year *i*

$G_{g,i}$ = *Total generation of generating unit g* in year *i*

$CP_{g,n,i}$=*Marginal impact from common pollutant n for each generating unit g in year i.*

Table 2.14 is a breakdown of the per ton common pollutant damage, for Georgia Power's system, in 2015-$. The AP2 model is a standard integrated assessment model that connects emissions to monetary damages through six modules: emissions, air quality modeling, concentrations, exposures, physical effects, and valuation. (For a complete description of the AP2 model see Muller, 2011). The primary benefit of the AP2 model is its spatial detail and that it is calibrated to compute marginal damages. When valuing the impacts on goods traded in markets (crops, for example), AP2 uses market prices. The AP2 model provides estimated impacts based on height of emissions source. In my assessment, we used cost estimates based on emissions sources greater than 500 ft (or the highest available altitude), corresponding to thermoelectric power plants. When valuing changes in health, the model uses the Value of a Statistical Life (VSL) approach (Viscusi, Aldy, 2003). AP2 is calibrated to use a VSL of $6 million. (USEPA, 2016; Fann et al., 2012). Currently, the AP2 model can compute marginal damages for the five pollutants over four data years at nearly 10,000 individual and grouped sources in the contiguous U.S. There is no discount rate applied to common pollutants, as the impacts of common pollutants are direct, meaning that the surrounding community feels the physical impacts of exposure to pollutants immediately.

Table 2-14-Damage Cost of Common Pollutants in Georgia Power's region

Pollutant	**Damage (2015-$)***
PM 2.5	6,450 – 9,940
SO2	5,550 – 6,360
NOx	715 – 769
NH3	6,240 – 10,600
VOC	614 – 910
PM 10	185 - 360

**Range of damage due to variations in stack height and location*

2.7.8 Carbon Impacts

Unlike conventional generating sources, distributed solar emits no carbon during generation. To determine the amount of reduced carbon generation, I evaluate the amount of carbon (in tons) displaced for every MWh of solar generation. Following the same methodology for common pollutants, we utilize EPA's Air Markets Program Data (AMPD, 2016) to calculate tons of carbon emitted from each generating unit corresponding to my baseline generation profile to determine a marginal cost in $/ton. We use the central estimate of the social cost of carbon (SCC), an estimate of the monetized damages associated with an incremental increase in carbon emissions per ton.

Equation 2.6 Marginal Impact from Carbon

$$SC_{g,i} = \frac{C_{g,i}{}^{*} \cdot SCC}{G_{g,i} \cdot \gamma}$$

$C_{g,i}$= *Carbon Emissions in tons per generating unit g in year i*

SCC= Social Cost of Carbon in $/ton

$G_{g,i}$= *Total generation of generating unit g* in year *i*

$$\gamma \equiv \frac{1}{1+r} = discount\ rate$$

$SC_{g,i}$ =*Marginal impact from carbon for each generating unit g in year i.*

The SCC includes (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. The current central value for the SCC reported by the Interagency Working Group of the federal government is $39 per ton (2009-$) in 2015 (Interagency Working Group on Social Cost of Carbon, 2015); this value increases year-to-year as damage from the marginal ton of CO_2 is anticipated to increase over time. Following precedence set by the Office of Management and Budget (OMB Circular A-4) on evaluating carbon impacts, a discount rate of 3% was applied over the modeling horizon, resulting in a value of 2.2c/kWh.[18]

2.7.9 Environmental Market Value

Distributed solar is an emission-free, clean resource. As such, it provides additional value in existing markets that is not present with traditional fossil fuel assets, and which is not therefore captured through deferred asset valuation. This additional market value can be represented with a renewable energy credit (REC). REC prices depend upon the technology source, the vintage, the purchase volume, the generation region, whether state policies deem them eligible for certification, and whether the RECs are bought for compliance obligations or to serve voluntary retail consumers. Solar renewable energy credits (SRECs) are RECs specific to solar generation.

Often RECs are used to comply with Renewable Energy and Energy Efficiency Portfolio Standard (REPS) and the value of RECs are based on the cost of a utility's compliance. Currently, Georgia does not have a RPS, and it is questionable whether it will in future years. Thus, there is no data to measure the value of REPS compliance by purchasing an unbundled

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[18] Three percent values an environmental cost or benefit occurring 25 years in the future at about half as much as the same benefit today. See: W.D. Nordhaus, Managing the Global Commons: The Economics of Climate Change (MIT Press 1994)

REC, if DG solar RECs were not available. Open SREC markets are different from compliance REC markets. Compliance RECs generally must be sourced from within some geographic region to be eligible for RPS compliance. Since no such market exists in Georgia, the only proxy estimate is a voluntary REC market price. Voluntary RECs can be sourced either regionally or nationally. It should be noted that in voluntary markets, RECs may sell at a premium if they are competing with RECs used for RPS demand, or are from regions with limited renewable resources. To proxy the value of RECs in GPC, we use low estimates from voluntary REC markets, which we estimated at 1c/kWh. REC prices have varied dramatically over the past few years; however, values have been relatively stable since early 2014. The value chosen represents the low-end of the REC and SREC values. The low-end SREC value is reflective of the current market for all RECs, including wind and other renewable sources (Flett Exchange, 2016). The REC values were discounted accordingly under the three different discount rates over 30-years.

Table 2-15-Estimates of SREC Value

Discount Rate	Value	Levelized c/kWh
3%	SREC	*0.55*
5%	SREC	0.31
8%	SREC	0.27

2.8 Results

When accounting for all of the components in our VOS methodology, under three different discount rates (3%, 5%, 8%) I find that the value of DGPV in Georgia ranges from 13.58 c/kWh to 14.4 c/kWh. When accounting for sensitivity analysis around projected fuel prices and the ELCC of DGPV, for all three components our estimates range from 7.59 c/kWh to 17.2 c/kWh. If I only include costs and benefits to the utility, our estimates drop to 4 c/kWh to 13.64 c/kWh. Comparatively, my numbers are similar to other studies conducted in the region including Synapse (2015) and Crossboarder (2013), with a respective 12.5-22 c/kWh and 10.4 – 11.3 c/kWh for residential customers. However, my estimates are much lower than other studies, such as estimates by Norris et al (2015) which found a Value of Solar of 33 c/kWh in Maine.

Table 2-16-Components of Value of Solar and Associated Benefits

	Benefits to the Utility					Costs to the Utility	Environmental/Societal Benefits		
	Avoided Energy	Avoided Generation Capacity	Avoided Ancillary Costs	Avoided Line Losses	SREC	Integration Costs	Avoided Carbon	Avoided Common Pollutants	
Discount Rate	Levelized c/kWh	Levelized c/kWh	Levelized c/kWh	Levelized c/kWh	Levelized c/kWh	Levelized c/kWh	Levelized c/kWh	Not Levelized	**Total (c/kWh)**
3%	*4.2*	*3.8*	*1.09*	*0.56*	*0.55*	-0.22	*2.2*	*1.4*	**13.58**
5%	*3.5*	*4.5*	*1.1*	*0.56*	0.31	-0.15			**13.42**
8%	*3.0*	*5.8*	*1.2*	*0.61*	0.27	-0.08			**14.4**
Sensitivity	*3-5.95*	*.39-5.8*	*.57-1.4*	*.25-.71*					***7.59-17.2***

I also estimated the impacts of decreasing the levelized period from 30 to 20 years. Decreasing the time-period, effectively increases the estimates by an average of 2.8%, as it reduces the expected energy cost savings by an average of 14% but increases the expected capacity value by an average 12%.

While I attempted to model the variations in VOST estimates, there are a number of variables that we did not provide sensitivity analysis around that could impacts our results, including the heat rate of the natural gas combustion turbine utilized to estimate energy and capacity values, the estimates of line losses, and the generation source used to estimate energy and capacity values. Changes to any of these would also impact the results. Moreover, I do not make any assumptions on how greater penetration rates of DGPV on the system may shift values, including the ELCC and the integration costs. A more thorough analysis under different penetration rates would help to better understanding the changing nature of DGPV's value.

2.9 Conclusions

In order to transition the United States away from fossil fuels and towards more sustainable sources of electricity production, there must be a fundamental shift in the regulation of the incumbent utilities and pathways for facilitating technological innovations. Throughout the country PUCs, as gatekeepers of the regime business model, are increasingly tasked with dictating the mechanisms and pace of transition. These dynamics are ever apparent in the growth of DGPV and policies identified to foster adoption. Historically, rapid diffusion of the NEM policies served to grow the niche innovation. Now as the adoption of DGPV has accelerated, the technology challenges the incumbent regime and the policy structures that support its dominance.

Against these sociotechnical dynamics, the use of a VOST is growing as a potential policy tool for incorporating DGPV into the regime. Given the weight that a VOST may hold for the future of DGPV and other technological innovations, more research is needed on the dynamics and implications of this complex policy tool. In this chapter, a VOS evaluation for distributed solar in Georgia Power Company's territory was conducted, under various methodological scenarios, producing a range in value of solar of 7.59c/kWh-17.2c/kWh. My estimates included the costs of integrating distributed generation, as well as the benefits from avoided energy, avoided generation capacity, avoided ancillary costs, avoided line losses, SREC sales, avoided carbon emissions, and avoided common pollutants. There were a number of components, particularly those specific to the transmission and distribution system, that we were unable to estimate. Moving forward, greater information on Georgia Power's grid will improve upon the VOS evaluation, particularly in terms of determining a potential locational value of solar for capacity deferral.

The case study highlights that the methods and estimates employed to value DGPV will greatly impact the ultimate results. Likely the two greatest variables impacting the overall value of DGPV, for this study, are the projections of natural gas prices and the ELCC applied to DGPV. For stakeholders, this highlights the need for empirical studies on the ELCC of DGPV before engaging in VOS methodologies. Moreover, the orientation of the solar array will also impact the ELCC and potential the avoided energy costs associated with DGPV. This means that ELCC studies should include analysis with different DGPV system orientations. Similarly, recognizing the variability in natural gas prices, stakeholders should conduct multiple sensitivity analyses around the forecasted costs. Another interesting finding is that our lowest estimate of DGPV's value to the grid is equivalent to the current export rate for GPC, suggesting that GPC is greatly undervaluing DGPV, and that our average estimate is comparable to retail-rate NEM for residential customers, at 12.4c/kWh. This suggests that NEM may be an adequate and compromise measure for estimating the current value of DGPV.

As the process of assigning a market valuation to DGPV spreads across jurisdictions, it is critical that policymakers and engaged stakeholders begin to work towards a uniform framework for VOS studies. Determining what cost and benefit categories should be included, the underlying data and the calculation methods that should be employed, as well as the timeline framework of the study are critical to establishing a process that is ultimately repeatable by multiple parties. What policy makers have learned from NEM is that ascribing value to exported solar energy equivalent to retail rate will spur the market for adoption. Implementing a VOST can potentially improve or damper the adoption rates, depending on the calculated value.

When determining the applicable discount rates, particularly with environmental and societal components, policy makers must again determine the value of a resource to future generations. Additionally, policymakers must determine how to handle critical and sensitive inputs such as fuel price projections and ELCC. Ideally, with more research and publicly available data, variables such as ELCC and distribution capacity value can be determined with empirical analysis. For other sensitive variables, such as projected fuel costs, there must be agreement on a reasonable projection that balances risk to both the utility and the customer. Moving forward less emphasis should be placed on the differences in the VOST estimates, and more emphasis should be placed on the implications of the framework and the methods that dictate the VOST.

Moreover, regulators and stakeholders must recognize the implications of establishing a VOST, the precedence it may set, and that the methods employed in a VOS methodology will shape the market for DGPV and reflect the residing policy and societal priorities. Determining which cost and benefit components to include ultimately define the future market for DGPV. Moving forward, PUCs must decide whether the value that one technology provides to society should be dictated by the cost structure of another market player or what the appropriate bounds of comparison might be. These decisions will hold weight for the future market of electricity generation, the pace of technological adoption and diffusion, and the capacity for sustainable transition.

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2.11 Appendix

Table 2-17 A.1 Summary of data sources used for VOS methodology

2015	January	February	March	April	May	June	July	August	September	October	November	December
1	9620.279	9047.643	7959.945	7594.394	8189.938	9605.12	9972.301	9838.722	8613.836	7622.771	8058.907	9015.152
2	9556.321	8972.428	7853.914	7424.303	7934.03	9224.213	9593.474	9502.285	8362.791	7478.742	7954.32	8887.185
3	9602.893	9026.634	7872.777	7397.943	7830.056	9033.077	9394.643	9338.689	8255.945	7464.068	7948.942	8878.67
4	9824.983	9250.07	8099.108	7585.162	7945.631	9072.592	9428.836	9428.782	8378.149	7655.603	8120.516	9033.366
5	10348.71	9808.193	8676.793	8109.311	8352.288	9354.46	9698.883	9860.144	8850.872	8192.984	8573.25	9456.254
6	11225.98	10750.65	9497.378	8718.989	8853.506	9757.615	10071.21	10378.31	9417.887	8882.907	9293.256	10169.1
7	11768.65	11243.47	9903.143	9065.242	9287.636	10343.88	10575.7	10786.51	9774.743	9267.352	9735.199	10713.22
8	11834.85	11284.57	9968.869	9333.324	9780.847	11119.5	11338.58	11378.73	10169.17	9437.398	9918.019	10875.63
9	11726.89	11169.57	10026.37	9604.407	10305.06	11964.41	12204.62	12120.64	10722.14	9676.406	10009.35	10895.44
10	11572.99	11031.66	10070.13	9815.321	10803.04	12797.28	13085.29	12894.63	11286.78	9872.963	9947.023	10808.51
11	11315.82	10777.83	9996.694	9962.794	11222.64	13529.27	13835.41	13587.46	11794.48	10001.19	9861.921	10624.36
12	11048.17	10537.86	9934.067	10085.99	11579.64	14092.11	14432.45	14166.04	12247.83	10099.15	9727.457	10393.86
13	10804.26	10325.94	9869.45	10193.46	11884.59	14520.8	14845.26	14596.32	12607.49	10177.87	9264.749	10199.59
14	10568.98	10128.49	9789.443	10256.91	12101.55	14797.18	15089.05	14881.8	12858.63	10247.3	9505.374	10022.56
15	10412.7	9977.622	9716.978	10341.67	12267.91	14983.92	15259.72	15057.17	13035.88	10202.9	9406.795	9901.87
16	10426.97	9942.578	9653.827	10282.72	12210.37	14880.58	15142.26	14944.63	12947.91	10146.86	9387.89	9940.246

Table 2-17 (Continued)

17	10739.68	10041.33	9596.263	10166.27	12015.15	14622.07	14876.34	14687.46	12690.18	10014.61	9638.033	10352.52
18	11452.94	10605.82	9697.956	10007.95	11700.46	14206.28	14451.8	14280.76	12342.15	10072.9	10074.56	10856.41
19	11573.31	10944.09	10015.35	10044.69	11440.89	13749.79	13977.07	13915.75	12186.9	10245.83	10110.25	10991.54
20	11490.58	10865.71	10111.82	10125.8	11291.51	13372.18	13618.65	13607.92	11949.08	10025.13	9947.645	10875.01
21	11192.51	10568.97	9747.709	9741.452	10881.39	12910.82	13142.45	12962.36	11250.37	9524.58	9628.06	10635.7
22	10723.66	10092.73	9188.765	9073.998	10081.18	11968.2	12253.37	11999.11	10397.55	8913.642	9183.774	10210.65
23	10229.94	9582.965	8619.04	8402.243	9268.516	10995.58	11313.37	11067.7	9599.532	8327.307	8705.526	9704.88
24	9860.298	9204.553	8192.002	7913.833	8642.038	10202.4	10534.27	10331.5	8981.49	7894.056	8322.219	9269.139

The data provided in Table A.1 is pulled from FERC form 714 which provides hourly demand profiles for balancing authorities.

Table 2-18 Estimated Baseload, Peak and Purchase Emission Estimates

BASELOAD GPC Characteristics	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	5654.0	5848.5	647.8	5031.6	556.5	168.1	36.68	
Tons Emitted	0	1910	38245	109907	548	3532	40275376	
Net Generation	0	61010000	61010000	61010000	61010000	61010000	61010000	
Tons/MWh	1.51472E-05	3.13062E-05	0.000626868	0.001801459	8.98973E-06	5.78883E-05	0.660143851	
Damage ($)/MWh	0.09	0.18	0.41	9.06	0.01	0.01	24.22	33.97

NON-BASELOAD GPC Characteristics	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	9,565.00	9,015.39	697.59	5,763.82	824.84	326.67	36.68	
Tons Emitted	0	0	0	0	0	0	0	
Net Generation	-	-	-	-	-	-	-	
Tons/MWh	7.4192E-07	8.26125E-07	0.003091196	1.99391E-05	3.68716E-07	1.00178E-06	0.024393035	
Damage ($)/MWh	0.01	0.01	2.16	0.11	0.00	0.00	0.89	3.18

Purchased GPC Characteristics*	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	6,436.17	6,481.85	657.76	5,178.08	610.16	199.79	36.68	
Tons/MWh	1.22661E-05	2.52102E-05	0.00	0.00	7.26553E-06	4.6511E-05	0.60	
Damage ($)/MWh	0.08	0.16	0.29	1.67	0.00	0.01	21.92	
								24.14

The data provided in Table AI.2 is pulled from Energy Information Administration, Forms 923 and 860, and the Environmental Protection Agency National Emissions Inventory and is calculated based upon the methodology outlined in chapter IV. For purchased power estimates, the SERC average was used, provide by the EI

Table 2-19 Generation Purchases for 2016

2016 Purchased	J	F	M	A	M	J	J	A	S	O	N	D
0	3376	2803	1716	1350	1946	3361	3728	3595	2370	1379	1815	2771
1	3312	2728	1610	1180	1690	2980	3349	3258	2119	1235	1710	2643
2	3359	2782	1629	1154	1586	2789	3150	3094	2012	1220	1705	2634
3	3581	3006	1855	1341	1701	2828	3185	3185	2134	1411	1876	2789
4	4105	3564	2433	1865	2108	3110	3455	3616	2607	1949	2329	3212
5	4982	4506	3253	2475	2609	3513	3827	4134	3174	2639	3049	3925
6	5524	4999	3659	2821	3043	4100	4331	4542	3531	3023	3491	4469
7	5591	5040	3725	3089	3537	4875	5094	5135	3925	3193	3674	4631
8	5483	4925	3782	3360	4061	5720	5960	5876	4478	3432	3765	4651
9	5329	4787	3826	3571	4559	6553	6841	6650	5043	3629	3703	4564
10	5072	4534	3752	3719	4978	7285	7591	7343	5550	3757	3618	4380
11	4804	4294	3690	3842	5335	7848	8188	7922	6004	3855	3483	4150
12	4560	4082	3625	3949	5640	8277	8601	8352	6363	3934	3021	3955
13	4325	3884	3545	4013	5857	8553	8845	8638	6614	4003	3261	3778
14	4168	3733	3473	4097	6024	8740	9016	8813	6792	3959	3163	3658
15	4183	3698	3410	4039	5966	8636	8898	8700	6704	3903	3144	3696
16	4495	3797	3352	3922	5771	8378	8632	8443	6446	3770	3394	4108

Table A-3 (Continued)

18	5329	4700	3771	3800	5197	7506	7733	7672	5943	4002	3866	4747
19	5246	4622	3868	3882	5047	7128	7374	7364	5705	3781	3703	4631
20	4948	4325	3504	3497	4637	6667	6898	6718	5006	3280	3384	4391
21	4479	3849	2945	2830	3837	5724	6009	5755	4153	2669	2940	3966
22	3986	3339	2375	2158	3024	4751	5069	4824	3355	2083	2461	3461
23	3616	2960	1948	1670	2398	3958	4290	4087	2737	1650	2078	3025
SUM (MWh)	109062	95321	74197	71387	96009	141242	148274	145753	108861	71584	72462	92850

The data provided in Table AIII.3 was calculated by the methodology provided in Chapter IV. The data is the estimated average hourly purchased power by GPC for each month in 2016 after accounting for estimated baseload and peak production. The sum of these estimates are checked against GPC's 2015 Annual Report.

Table 2-20 Estimated Available Hourly Generation for Baseload and Peak

2016	Baseload (MWh)	Peak (MWh)
January	6076.60	167.60
February	6076.60	158.71
March	6076.60	145.04
April	6076.60	143.22
May	6076.60	159.15
June	6076.60	188.43
July	6076.60	192.98
August	6076.60	191.35
September	6076.60	167.47
October	6076.60	143.34
November	6076.60	143.91
December	6076.60	157.11

The data provided in Table A.4 is the estimated baseload and peak generation determined by the methodology explained in Chapter 2.

CHAPTER 3. ASSESSING THE LEGITIMACY OF THE COST SHIFT: EVALUATING THE IMPACTS OF A VALUE OF SOLAR TARIFF AND NET ENERGY METERING ON SOLAR-PARTICIPANTS AND NON-PARTICIPANTS

3.1 Introduction

As a developing niche technology, DGPV is feasible and in many cases at or near the cost of regime technologies, namely fossil-fuel generation. In many areas of the United States, DGPV is now competing as a mainstream resource for electricity generation. For example, in many states throughout the country DGPV has hit grid parity (Greentech media, 2017). Incumbent utilities have become alarmed at the growth of potential for DGPV to undermine their current business model and stronghold on the electricity market and have mobilized to slow it. Utilities have used several strategies to resist the growth of DGPV. Publicly, utilities voice concerns about the threat to jobs in fossil-fuel industries, the high cost of renewable energy, and the technical problems of managing an electricity grid based on intermittent energy sources (Hess, 2015).

One of the biggest arguments made by utilities against DGPV, which is often in toe with arguments made about NEM, is that the expansion of DGPV will result in revenue erosion and inadequate cost recovery for the utility, resulting in a shift of costs to non-solar customers. Some utilities argue that any policies or programs that incentivize the growth of DGPV and provide compensation above the avoided cost of generation will result in a cross-subsidization between non-solar and solar customers. Other utilities argue that just the adoption of DGPV generally, without any compensation for exported power, will reduce utilities ability to recover costs and earn a rate of return guaranteed by the PUC. As a result, the utility must maintain that revenue and guaranteed profits by increasing costs on other customers (Borlick and Wood, 2014; Brown and Lund; 2013, Brown et al, 2015). DGPV advocates argue that DGPV provides multiple benefits to the grid above the avoided cost of generation and that any potential impact of reduced revenues should be weighed against the benefits of DGPV for both solar and non-solar customers. This argument is most frequently referred to as the 'cost shift' argument.

Despite the growth in NEM and the growing number of VOS studies, few examine the potential for a 'cost shift' and address the concerns consistently voiced by utilities. The transition studies literature recognizes that incumbent organizations will try to capture multiple strategies to capture the policy process and turn it to their favor (Voß et al., 2009), which have variable rates of success. The few academic pursuits in this field have recognized that the fears over DGPV adoption voiced by the incumbent utility are likely exaggerated (Johnson, et al, 2017). As Hess (2015) points out, more analysis is needed to evaluate the legitimacy of these strategies used by regime actors to inhibit niche growth.

In this chapter I build on the work by Hess (2015) and Johnson et al (2017) an examine the legitimacy of the largest argument made by the incumbent utilities against the growth of DGPV- the 'cost shift.' I expand on the work conducted in Chapter 3 by assessing the implications of implementing the estimated VOST in Georgia. I utilize GT-DSM to estimate the impact of a VOST for DGPV exports on the residential customer classes, with the specific goal of discerning how an increased export rate for residential solar customers impacts the rates of non-solar customers.

Before moving on to outline my research questions, the purpose of this research needs to be clearly stated. The incumbent utility business model, which has been established and iterated on through various policy actions (legal, regulatory, and otherwise) over the past century, is inherently threatened by the growth of DGPV (Hess, 2015). However, the concern for those seeking to transition the electricity system away from fossil fuels and towards renewable resources, is an issue of time. As many have recognized (Hess, 2015; Geels, 2014; Geels et al, 2014) in order to facilitate the technological innovation necessary for transition, the utility business model, and the regulations which support it, must adapt. Slowing that adaptation is the power of incumbency and an industry-wide disinterest in innovation, as shown by low investments in research and development and the multiple strategies and arguments employed by the beneficiaries of the status quo. This research analyzes these strategies to assess their technical merit and political purpose, especially with regard to claims that state DGPV establishes cross-subsidization of one customer over another, referred to as 'cost-shifting'. If there is truth in the 'cost shift' argument, then policymakers, in as much as they are concerned with transitioning the electricity system, must decide how to adapt the incumbent utility business model (which will undoubtedly take years) while simultaneously ensuring the growth of niche innovations, like DGPV. Can regulators continue to support niche innovations and give themselves enough time to qualitatively change the policies that guide the regime? This research aims to begin assessing this critical policy question for the sustainable transition of our energy system.

3.2 Research Questions

This chapter seeks to answer two three questions.

Q1. How would the implementation of different VOSTs and NEM policies impact the market for residential solar in Georgia?

Q2. How would the implementation of a VOST or NEM impact the rates and bills of non-solar customers, i.e. what is the cost shift?

Q3. What do the results of this case study mean for the greater research on niche-regime dynamics and regulation in a sustainable transition?

To answer these questions, we first estimate the impact of three VOST estimates — 7.59c/kWh, 14.4 c/kWh, 17.2 c/kWh — and NEM on the residential solar market in Georgia. To do so we calculate a historical price elasticity of demand for residential DGPV and estimate how the implementation of each VOST and NEM impact the levelized cost of energy (LCOE) for BTM DGPV and market adoption rates. We use GT-DSM to estimate the impact of a VOST and NEM for DGPV exports on all residential customers, paying particular attention to the impact on rates and bills of non-solar customers. We compare the results of our VOS analysis with the implementation of NEM and the continued use of the current export rate for DGPV in Georgia, set at the avoided cost of energy. We then discuss the policy implications of both a VOST, NEM, and GPC's current export rate.

3.3 Description of GT-DSM

The Georgia Tech Demand Side Management (GT-DSM) is designed to analyze the impacts of policy or utility actions such as energy efficiency, demand response, and/or renewable energy development on the utility companies' financial status as well as the rates and bills faced by rate classes (both participants and non-participants). It was initially developed by Brown et al.

(2015) to examine alternative business models for energy efficiency in the Southeast. [19] I subsequently revised and expanded GT-DSM for the purposes of this dissertation.

GT-DSM integrates utility scale financial modeling with customer financial analysis capability. On the utility side, GT-DSM performs an aggregated utility-level analysis of the proposed portfolio by unpacking the change in fixed and variable costs to operate electricity generating assets and the resulting impact on return on equity and revenues. It does so by using historical chained CPI and historical annual operating costs, maintenance costs, and generation broken down by technology type to produce a historical breakdown of inflation-adjusted O&M costs per MWh by generating technology type. With the inputs of several years' values of the above-mentioned categories and a projected generation distribution among technologies for the future time series, the model can produce estimated total O&M and fixed costs for each technology type. When new capacity is added or additions are avoided, a capital investment or deferred capacity investment will be also calculated.

On the customer side, GT-DSM includes a characterization of the utility's current and future projected customer base, including both the residential sector and the commercial and industrial sector, in terms of number of customers, rates, and sectoral annual demand for electricity. Based on the energy savings and peak demand reduction, the module solves for the rate and bill impacts for multiple classes of ratepayers, calculates costs required to operate the portfolio and its associated impact on utility revenue. The module is also capable of computing the levelized cost of the portfolio, annual program cost recovery and revenue recovery, as necessary.

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[19] https://cepl.gatech.edu/projects/mecp/modeling

First, the module solves for the impacts of the portfolio on customers, particularly the impacts on their bills and on their rates. It can show the trajectory of the impact year by year, as well as the total impact over time, and can compare the impact of expanded energy efficiency programs to a base case. It is capable of showing impacts by customer class and can assess how impacts differ between participants in programs and non-participants. Second, GT-DSM includes a comparison of benefits to costs of the programs, based on the tests described in the California Standard Practice Manual: Participant Test, Ratepayer Impact Measure Test, Total Resource Cost Test (with the variant known as the Societal Cost Test), and Program Administrator Cost Test (also known as the Utility Cost Test).

Third, GT-DSM is capable of describing the impacts of the energy efficiency investments on the utility, particularly the impacts on earnings and Return on Equity. Its outputs allow assessment of the impacts on earnings and ROE of various approaches to compensation of the utility for the investments in energy efficiency. Last, GT-DSM computes the costs of the portfolio for the purpose of comparison to supply side alternatives, presented as levelized cost per kWh of energy saved or other measure of the cost of saved energy.

Data input for GT-DSM relies primarily on SNL, an industry intelligence service, through subscription only. SNL compiles the data mainly from the following sources: utility company financial filings, EIA Form 826, 906, 923, 412 (pre-2004), FERC Form 1, RUS 12, RUS 7, and EPA Clean Air Market Database.

3.4 Methods

3.4.1 Establishing a Growth Rate for DGPV in Georgia under VOST and NEM

To determine the expected growth in customer-sited DGPV from 2017-2020, we first established a historical price elasticity of demand for residential solar. Historical data on residential solar installations is limited to system size and total capacity. We were unable to retrieve any historical pricing data for residential solar. Because the focus of our research is on the implication of NEM and VOST, we needed to assess a price elasticity of demand based not just on the installation cost of solar but on the levelized cost of energy (LCOE), so as to include the value of export compensation. The LCOE identifies an average unit cost per kWh that aggregates the life cycle cost of all assets and resources associated with the electricity generation facility. For our analysis, we build on Comello and Reichelstein (2016), thus for distributed solar, the LCOE can be expressed as:

Equation 3.1 Levelized Cost of Energy

$$LCOE = w + f + c \cdot \Delta + EV$$

w = unit variable cost in year i

f = fixed operating cost in year i

c = capital cost in year i

$\Delta =$ tax credit on system install

$EV =$ compensation for the exported energy to the grid

For solar photovoltaic power, since there is no associated furl cost, there is no variable operating cost, meaning that w=0. The only tangible operating costs will be the expected operations and maintenance of the solar system over its useful life. We estimate the life-cycle cost of a solar facility by the following parameters:

$SP = system\ installation\ cost\ in\ dollars\ per\ kW$

$CF(t) = capacity\ factor\ at\ time\ \boldsymbol{t}\ in\ the\ first\ year$

T = *useful life on the system*

$\gamma \equiv \frac{1}{1+r} = discount\ factor\ based\ on\ capital\ r$

$x^{i\text{-}1} = degredation\ rate\ of\ the\ system\ impacting\ annual\ total\ output$

Fi = fixed operating cost in year i

We assume that the solar system generates power continuously for 8,760 hours. We assume that each subsequent year of installation, the solar system's efficiency degrades at a rate equal to $x^{i\text{-}1}$. At time t in year i, the capacity factor therefore is $x^{i\text{-}1} \cdot CF(t)$, with $1 \leq t \leq 8,760$. By using an LCOE calculation, we ignore any intertemporal variations in the capacity available during any given year and considers only the average capacity factor, CF, given by:

Equation 3.2 Capacity Factor

$$CF = \frac{1}{m} \cdot \int_0^m CF(t)dt$$

m ≡ 8, 760

At time *t* in year *i*, for residential solar in Georgia we assume an average capacity factor is 15% with 1 ≤ t ≤ 8, 760 (NREL, 2016). To obtain the levelized capacity cost per kWh, and the levelized fixed operating costs, we divide the total installation price of the system as well as the total operations and maintenance of the system by the discounted total number of kilowatt hours that can be obtained from an installation of one kilowatt of power:

$$c = \frac{SP}{m \cdot CF \cdot \sum_{i=1}^{T} x^{i\text{-}1} \cdot y^i}$$

$$f \equiv \frac{\sum_{i=1}^{T} F}{m \cdot CF \cdot \sum_{i=1}^{T} x^{i\text{-}1} \cdot y^i}$$

Currently there is no database that tracks the historical install costs of residential solar systems in Georgia from 2008-2016. Thus, we utilized regional average numbers from NRELs 'Tracking the Sun' database (NREL, 2016). We assume that the solar system generates power continuously for 8,760 hours, with a system life of 30 years. For residential solar, the only fixed operating costs are the costs associated with advanced metering, and the occasional O&M costs. To determine estimates of the O&M costs with residential solar we contacted local solar developers, our conversations resulted in an estimate of $80/kW (Moreland, 2016). For estimates on advanced metering infrastructure, we used costs from GPC recent ASI and SPI programs. I estimated $120 annually for metering infrastructure costs.

The next component of the LCOE is the tax factor, Δ. Since we are focusing only on residential solar, the only relevant tax impact is federal investment tax credits, which is currently set at 30% of the installed capital costs. [20] There are currently no state tax credits in Georgia. However, from 2008- 2014 Georgia did offer a tax credit of 35% of the cost of the system, these tax breaks were incorporated in the historical costs of the solar systems.

The final component of the LCOE is the *EV,* which I denote as the revenue generated from the exported energy. In our analysis, we assume that households pay a retail rate for electricity and are not on time-varying rates. I denote this rate by p. Under a feed-in-tariff (i.e, a VOST or an RNR tariff,) the solar electricity sold back to utility is credited at a specific rate of e per kWh, or the export rate. Meaning that any generation that exceeds demand in a given hour is sold at e per kWh. In the case of net metering, $e = p$. Our analysis assumes that the consumption of electricity by the household is unaffected by the decision to invest in a solar.

Therefore, the revenue generated from exporting electricity to the utility, at any point in time is equal to the feed-in-tariff rate e multiplied by the number of kilowatts eligible for rate e.

[20] We assume the timeline for the residential ITC- 30% through 2020, after which the ITC then steps down to 26 percent in 2020 and 22 percent in 2021. After 2021, the residential credit will drop to zero

Assuming a load profile of *L(t),* in our analysis we estimate a *z(k)*, which the percentage of all kilowatt hours generated by the solar system of size *k* that is eligible for the rate, *e.* We denote z(k) as:

Equation 3.3 Percentage of kWh generated by Solar

$$zi(t|k) = \min\{L(t), CF(t) \cdot k \cdot x\ i{-}1\},$$

$$z(k) \equiv \frac{1}{m \cdot CF \cdot k \sum_{i=1}^{T} x^{i-1}) \cdot \gamma^{i}} \cdot \sum_{i=1}^{T} [\int_{o}^{m} zi\left(\frac{t}{K}\right) dt \cdot yi]$$

Thus, I estimate that for each system, size *k,* the estimated EV is equal to:

Equation 3.4 Revenue Generated from Exported Energy

$$EV = z(k) \cdot e$$

When determining EV, I recognized the connection between the system size and the compensation structure. With very low compensation for the export of solar power, system sizes will be scaled to avoid exporting power back to the grid. This concept is often referred to as 'right-sizing.' However, under favorable compensation, customers will size systems to take advantage of the potential revenue. Figures 10 and 11 represent the difference between a right-sized residential solar system and system sized to take advantage of favorable export compensation. The blue curve in Figures 10 and 11 represents the average electricity consumption of a typical household in Atlanta, GA on February 2 and August 5. In Figure 10 most of the electricity generated will be valued at the going retail rate, as household consumption exceeds production of the solar system. By comparison, Figure 11 depicts a larger solar installation and now a greater portion of the generation is valued at the export compensation rate.

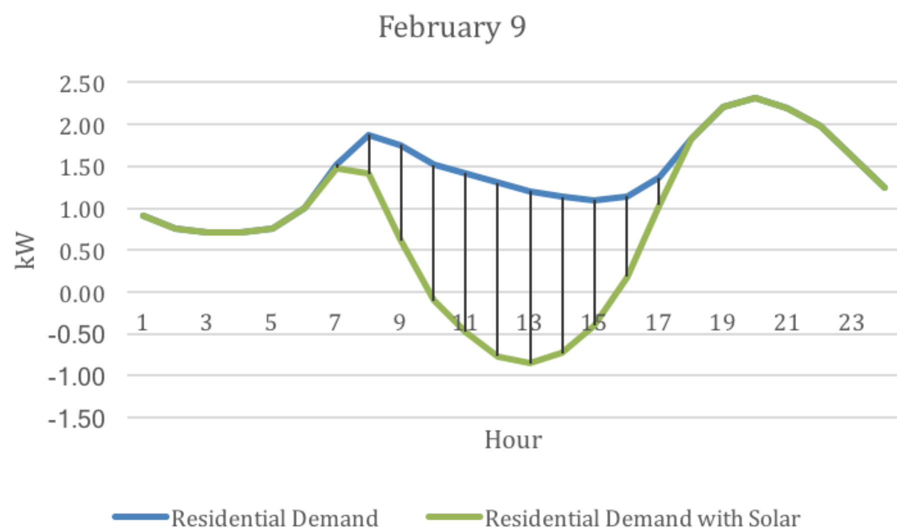

Figure 3-1a-Residential Demand with a Right-Sized Solar System

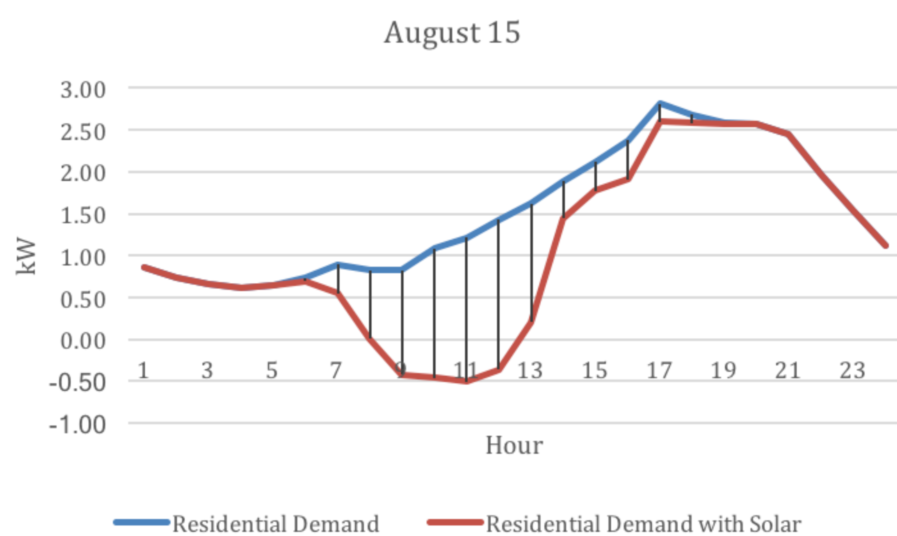

Figure 3-2b-Residential Demand with a Right-Sized Solar System

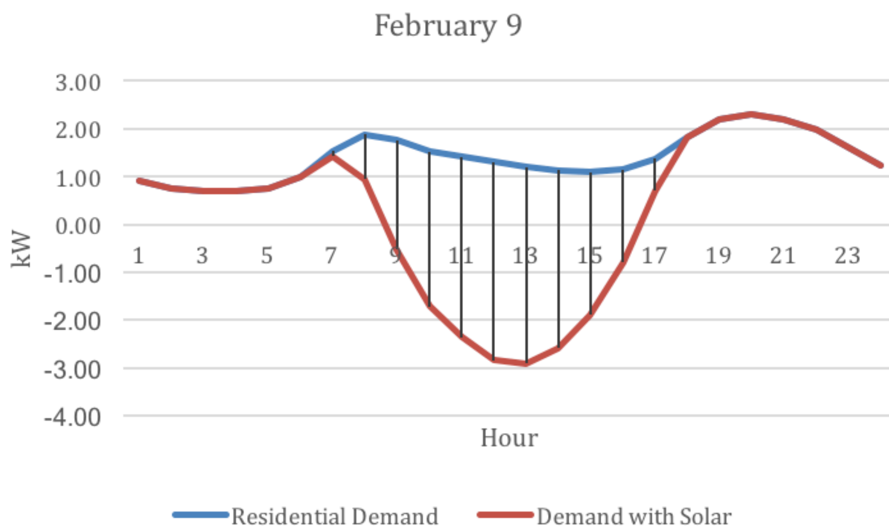

Figure 3-2a Residential Demand with a Large Solar System

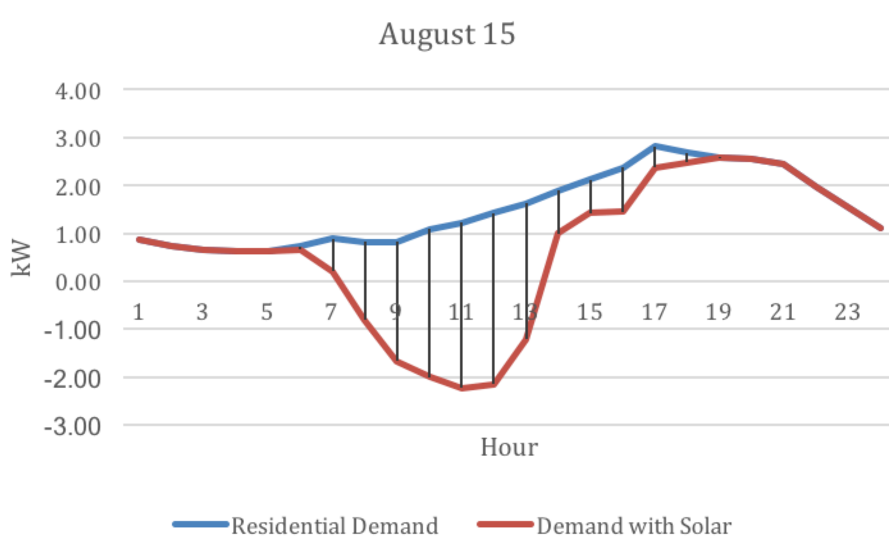

Figure 3-3b Residential Demand with a Large Solar System

To determine how residential customers have historically sized solar systems, and thus the total *z(k)*, I spoke with local residential solar developers (Moreland, 2016). Our research found that historically many customers have not applied for the RNR program as the potential value generated from exporting, EV, is not greater than the cost of the advanced metering necessary to enroll. However, even the customers that do apply for RNR are not doing so with the expectation that RNR will be a major source of revenue and do not factor in any type of EV with their financial planning. The biggest determinants for sizing a residential system are roof space and shading (typically from nearby tree cover). Developers in the residential space estimate that on average, 15% of the generation from a solar system is exported to the grid, primarily during the week due to low demand (Moreland, 2016). To understand how the size of a solar system may increase under favorable compensation, I examined installation sizes in California, Massachusetts, and Arizona — the leading states for residential solar (EIA, 2016). Our review concluded that the average residential system exports 25%-30% of total system output to the grid. In my analysis, we assume that 15% of all generation under RNR will be exported to the grid and that under a VOST or NEM, 27% of all residential solar generation is exported.

Determining how to capture the value of export compensation was critical for estimating the price elasticity of demand in Georgia. For two years, GPC offered solar customers favorable export compensation under the SP-1 and SP-2 programs. A review of the historical installation data revealed that under the SP-1 and SP-2 programs total capacity increased substantially, compared to years when only the RNR program was offered. As such we assumed that historically, the sizing of residential systems would respond to the favorable export compensation. Meaning that under years when only RNR is offered, only 15% of total system output is valued at an RNR rate of *e*= \$4c/kWh. For historical years when SP-1 and SP-2 were offered, we assume that installation sizes are larger and that 27% of total solar generation is exported to the grid. For forecasting impacts under NEM or VOST, we also assume that 30% of total solar generation is exported to the grid. For VOST, this means that 27% of total system generation is compensated at a rate of *e*= 7.59c/kWh, 14.4 c/kWh, 17.59 c/kWh. Under NEM, EV is compensated at a rate equivalent to the projected retail rate. Table 20 provides GT-DSM's estimates GPC's residential retail rate over the next ten years.

Table 3-1 GT-DSM's Estimates of Projected Retail Rates for GPC

2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
12.27	12.27	12.27	13.12	13.12	13.12	14.92	14.92	14.92	16.85	16.85

Table 3.2 provides the estimates for the LCOE for residential solar from 2010-2026 under and RNR rate, a NEM rate, and a VOST. For years 2016-2026 we assume a continued price decline of 10% annually in solar installation costs but make no adjustments to the average O&M costs. Once producing historical estimates for the LCOE (where *e*= 4 c/kWh and *z(k)*= 15%), we combined our calculations with total historical capacity numbers from 2008-2016, provided from the Southface Energy Institute's Georgia Solar Energy Dashboard (Southface, 2016). While changes in subsidies for solar lead to significant year to year variation in installations, an average price elasticity of demand for residential solar over this period was estimated at -0.95. Under an

RNR tariff, the LCOE of solar is not equivalent to (or achieve grid parity) to current average GPC residential retail rate of 12.27 c/kWh until 2019. Under NEM or a VOST, the LCOE of solar hits grid parity in 2017.

Table 3-2 Projected LCOE of Residential Solar under Different Compensation Mechanisms

		LCOE (c/kWh)				
	Install Cost $/W	LCOE-RNR	LCOE-NEM	LCOE-VOST (7.59 c/kWh)	LCOE-VOST (14.4 c/kWh)	LCOE-VOST (17.2 c/kWh)
2016	$ 2.79	16.4	10.02	11.89	9.33	8.08
2017	$ 2.51	14.9	8.55	10.55	7.99	6.73
2018	$ 2.26	13.6	7.34	9.34	6.78	5.53
2019	$ 2.03	12.03	6.05	8.25	5.70	4.44
2020	$ 1.83	11.3	6.46	8.89	6.34	5.08
2021	$ 1.95	11.9	5.18	7.85	5.29	4.04
2022	$ 1.76	10.9	3.99	6.91	4.36	3.10
2023	$ 1.58	9.9	2.87	6.07	3.51	2.26
2024	$ 1.42	9	1.82	5.31	2.76	1.50
2025	$ 1.28	8.3	0.94	4.63	2.07	0.82
2026	$ 1.15	7.6	.20	4.01	1.46	0.20

Table 3-3 Historical LCOE of Residential Solar under Different Compensation Mechanisms

	Install Cost $/W	LCOE c/kWh	Export Compensation
2009	7.06	39.2	RNR
2010	6.19	34.2	RNR
2011	4.37	19.2	SP-1
2012	3.82	16.3	Sp-2
2013	3.36	19.4	RNR
2014	3.11	18.1	RNR
2015	2.93	17.1	RNR
2016	2.79	16.4	RNR

After determining a price elasticity of demand, we turned to projecting future capacity additions for residential solar under the current RNR, NEM, and a VOST. Figure 3a shows the projected capacity additions and participation growth of residential solar under the three potential export compensation mechanisms. If GPC continues to offer only RNR as a compensation mechanism for exported solar energy, we estimate that the adoption of solar will grow minimally at an average rate of 22% each year. However, by 2026, residential solar will only account for 1.5 MWs, which is less than 1% of the distributed residential solar potential in Georgia (Burr, Hallock and Sargent 2015). The introduction of NEM or VOST introduces a value to the customer that decreases the LCOE, thus increasing the expected adoption. Under NEM, we estimate the capacity of the residential solar market at 13.3 MW by 2026. Under a 17.2 c/kWh VOST, we estimate the capacity of the residential solar market at 13.7 MW by 2026. The growth rates begin to converge in 2026 as the expected retail rate for GPC and the VOST of 17.2 c/kWh begin to converge, with a retail rate estimated at 16.9 c/kWh.

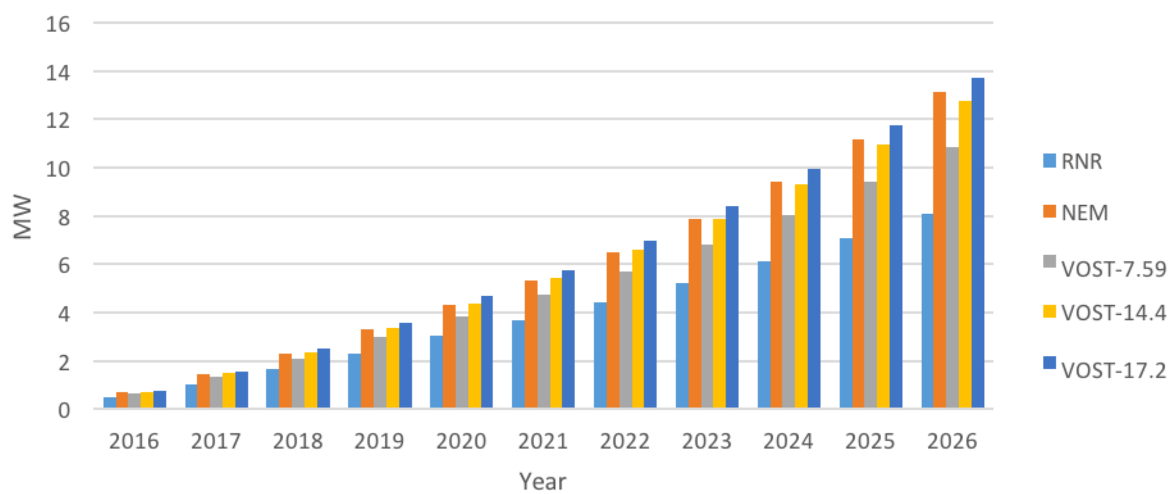

Figure 3-4 Expected Capacity Growth under different Compensation Mechanisms

Before determining the impact of RNR, NEM or a VOST on the rates and bill impacts of GPC customers, we first needed to determine how many participants would enroll in each program. To do so, we needed to estimate the average system size for residential customers. In terms of system size assumptions, the historical average installed capacity per system of a residential solar system in Georgia is 4 kW, with a historical average, annual load of 13,000 kWh. However, recognizing the potential that system sizes could increase under a VOST or NEM program, as customers are less financially motivated to 'right-size' their system, we assume an average residential system size of 4.75 kW, with no change to annual load.

3.5 Determining the Impact of a RNR, NEM and VOST tariff on Customer Bills and Rates

Given the low export rate under the RNR tariff, as well as limitations of systems sizes established by the Co-Gen Act, the majority of customer-owned DGPV in Georgia is predominantly BTM and designed either to generate up to the point where a host load is exactly equal to generation when summed over a typical billing period. While these systems, summed over the billing cycle, do not produce any net excess generation, they can produce excess generation during some hours of the day and do.

To date, only Minnesota and Austin, Texas have conducted a VOS methodology, with Austin being the only jurisdiction to have implemented a VOST over net metering. While any jurisdiction looking to implement a VOST has a variety of choices regarding several technical issues, that may have important impacts on costs to ratepayers, for the purpose of our analysis we model the implementation of a VOST to reflect the current established program in Austin.

We assume that the VOST will be established as a behind the meter program, meaning that customers only sell exported energy at the VOST and all demand not met by DGPV is purchased at the full retail rate. We also assume that all base charges implemented by GPC cannot be off-set by the VOST. For each billing month, the DGPV customer receives credit equal to the metered kilowatt-hour output of the customer's PV system multiplied by the VOST plus any carry-over credit from the previous billing month. Any remaining amount of credit(s) are carried forward and applied to the customer's next electric service bill. We also assume that all credits are only applicable to the usage where the on-site solar photovoltaic system is interconnected, meaning there is no virtual-metering. Finally, we assume that the VOST and NEM is established in August of 2016 and we model additions to the VOST program until 2026, but provide financial impacts until 2031.

The evaluation of bill and rate impacts for solar and non-solar customers as well as estimates of DG expansion were conducted under the following parameters and with the following assumptions. In all scenarios, we assume residential customers are on a time invariant rate structure, and that the export rates for each program are fixed over the modeling horizon. In the analysis of rate and bill impacts, the cost of the installed solar system is not included because these costs bear no impact on the utility financials. Additionally, the analysis assumes that all credits established under a NEM program are lost after 12-month cycle.

The GT-DSM model developed by Georgia Tech was used to evaluate the bill and rate impacts for residential solar-customers and non-solar customers, under a RNR, NEM, and a VOST export rate that compensates solar customers at the value of solar calculated above. To answer these questions, we use GT-DSM to determine how both the lost revenues because of residential solar as well as the compensation paid for exported solar, under each compensation mechanism, impact bills and rates for both solar and non-solar customers.

3.5.1 Variables for Estimating the Impact of Distributed Solar on Utility Financials, Rates, and Bills

GT-DSM uses four primary variables for estimating the impact of any utility program on rates and bills. The first is total capacity of energy savings, the second is the total number of participants. The third is each program's contribution to peak reduction. Peak reduction is estimated as a benefit to the utility and a mechanism for reducing overall system costs. To estimate the peak capacity reductions provided by residential solar, we generated hourly profile curves for each modeled year and matched the generation profiles to GPC's peak demand from 2015. Figure 13 provides the estimated peak reductions from distributed solar under the modeling horizon. By 2025, a 17.2 c/kWh VOST program can produce 11.1 MWs of peak capacity reductions. The final variable is the total cost of the program, which is equivalent to the EV paid under each compensation mechanism plus the cost of program administration, which we estimated at .5 c/kWh. Under a NEM program we assumed that there was no program cost to the utility, since there is no payout to the customer. All exported capacity is estimated as lost sales for GPC.

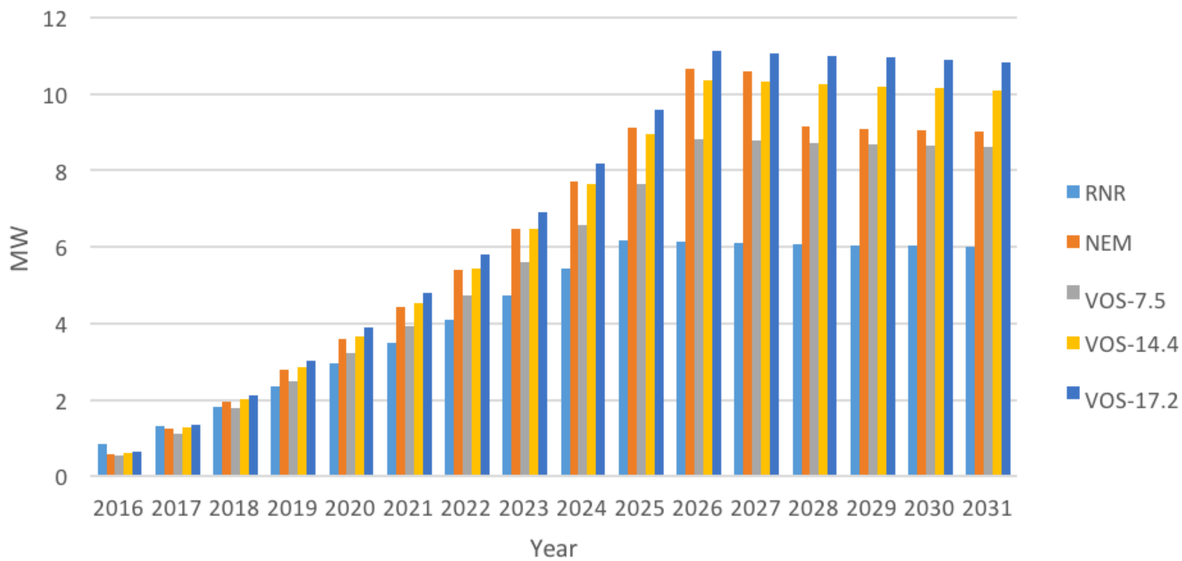

Figure 3-5 Estimate Peak Reductions from Residential Solar under different Compensation Mechanisms

Using the GT-DSM model, total net impact to the utility financials is a function of the total amount of solar generation; the rate base per customer class; the rate of return per customer class; the amount of solar exported the grid; the export compensation price; and the peak reduction provided from residential solar. Given that solar generation is often coincident with peak demand, any peak capacity reduction associated with solar output is considered a benefit to the utility and is translated into a variable cost savings.

3.6 Results: Expected Rate and Bill Impacts

In this section, expected rate and bill impacts for solar and non-solar customers under each compensation mechanism are evaluated. As noted, in this analysis the cost of the solar procurement is not included in expected participant bill impacts. Under all three VOST estimates, NEM, and RNR we observe no meaningful impacts on residential rates or non-solar bills. We present the findings for a 17.2 c/kWh VOST, NEM, and the continued RNR rate. All outputs are presented in the Appendix.

Under NEM or any VOST, average residential rates are essentially unchanged and the upward pressure on residential rates is unnoticeable. Under a NEM, average residential rates would increase by an average of 0.10%, or 0.0013 cents between 2016 and 2030, with a maximum increase of 0.25% or 0.0033 cents in 2030. Under a 17.2 c/kWh VOST, average residential rates would increase by an average 0.11%, or 0.0014 cents between 2016 and 2030, with a maximum increase of 0.23% or 0.0031 cents in 2030. Under a continued RNR, average residential rates would increase by an average of 0.07%, or 0.0009 cents between 2016 and 2030, with a maximum increase of 0.17% or 0.002 cents in 2030. The reason why the VOST actually results in a lower maximum bill increase, when compared to NEM, is because of the driving reduction in peak demand which limits even the marginal rate increase.

Despite the above retail rate payout from the VOST, there is almost no upward pressure on rates. This is in large part because solar reduces the variable cost of power for GPC at peak, the costliest time to generate power. Under a 17.2 c/kWh VOST, residential solar eliminates 192 MW of peak capacity through 2030, and results in a savings in the variable cost of production for GPC of $107 million. Under NEM solar eliminates 148 MW of peak capacity through 2030, corresponding to a savings in the variable cost of production for GPC of $106 million. The driving reason for NEM producing proportionately higher benefits than a VOST, is that under a NEM, there is no additional program cost for the exported energy only additional lost revenues. Under a continued RNR schedule, residential solar eliminates 132 MW of peak capacity, corresponding to a variable cost savings of $ 84 million. However, under the RNR tariff, the total compensation provided by GPC through 2030 is estimated at $130,423, suggesting that in fact it is the solar customers that are providing the subsidy to GPC.

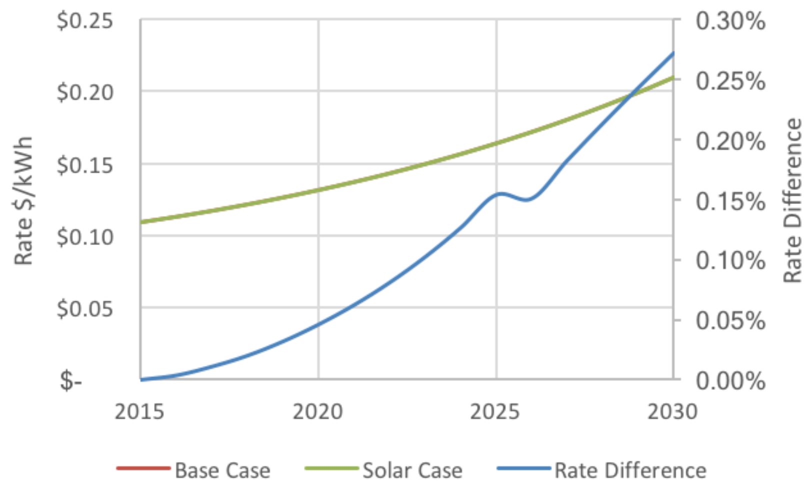

Figure 3-6 Impact of VOST at 17.2 c/kWh on Residential Rates, 2016-2030

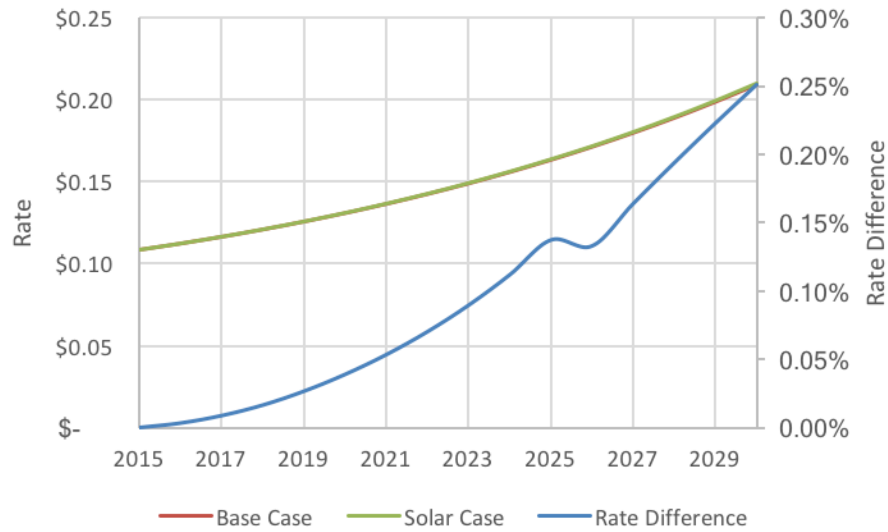

Figure 3-7 Impact of NEM on Residential Rates, 2016-2030

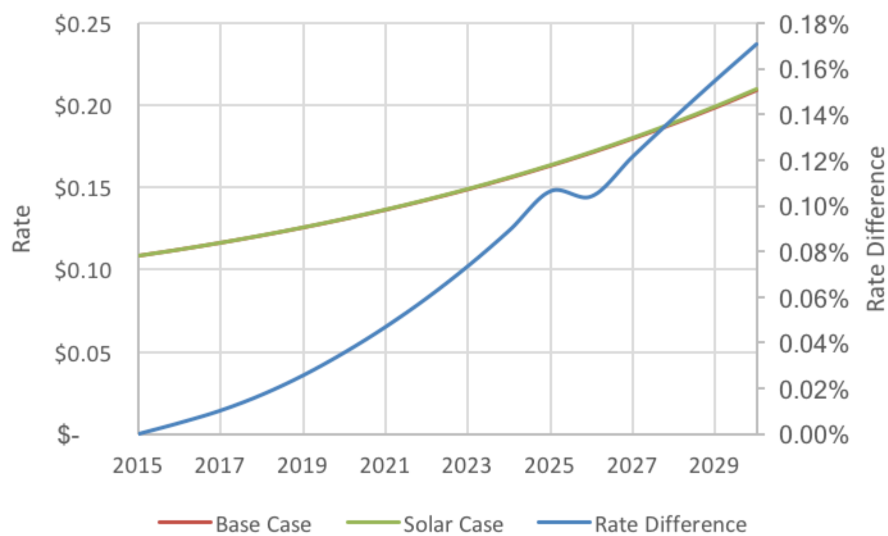

Figure 3-8 Impact of RNR on Residential Rates, 2016-2030

GT-DSM is also used to estimate the expected bill impacts for RNR, NEM, and VOST solar participants and non-solar participants with the implementation of each compensation mechanism. Under all three VOST estimates, NEM, and RNR we observe no meaningful impacts on non-solar residential bills. Under a NEM, average non-solar residential rates would increase by an average of 0.07%, between 2016 and 2030, with a maximum increase of 0.21% or in 2030. Under a VOST, average non-solar residential rates would increase by an average 0.09%, or between 2016 and 2030, with a maximum increase of 0.23% in 2030. Under a continued RNR, average non-solar residential bills would increase by an average of 0.05% between 2016 and 2030, with a maximum increase of 0.33% in 2030. The reason why the VOST actually results in a lower maximum bill increase compared to RNR is because of the driving reduction in peak demand which limits even the marginal rate increase.

Under a 17.2 c/kWh VOST, solar participants' bills are reduced by an average of 66% with an average monthly bill paid of $49. Under a NEM program, solar participants' bills are reduced by an average of 62% with an average monthly billed paid of $57. Under a continued RNR program, solar participants' bills are reduced by an average of 56% with an average monthly billed paid of $69.

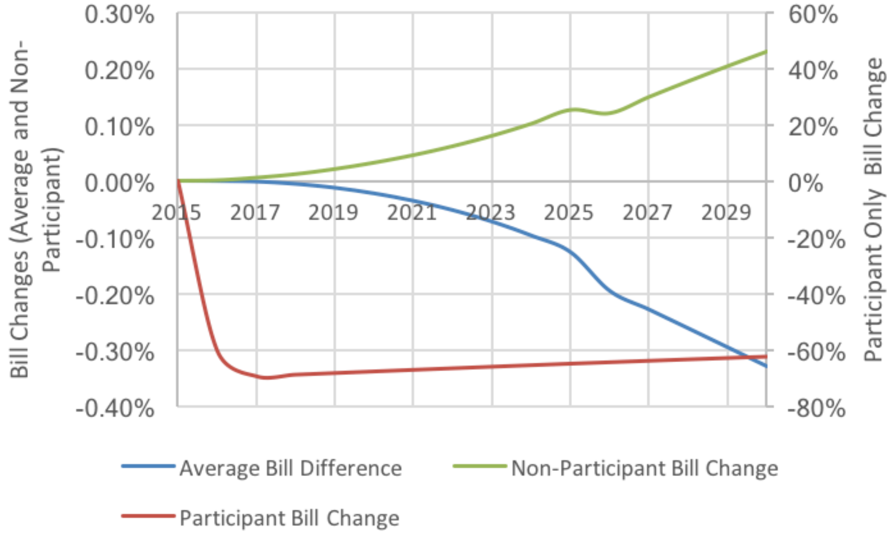

Figure 3-9 Impact of VOST at 17.2 c/kWh on Residential Customer Bills, 2016-2030

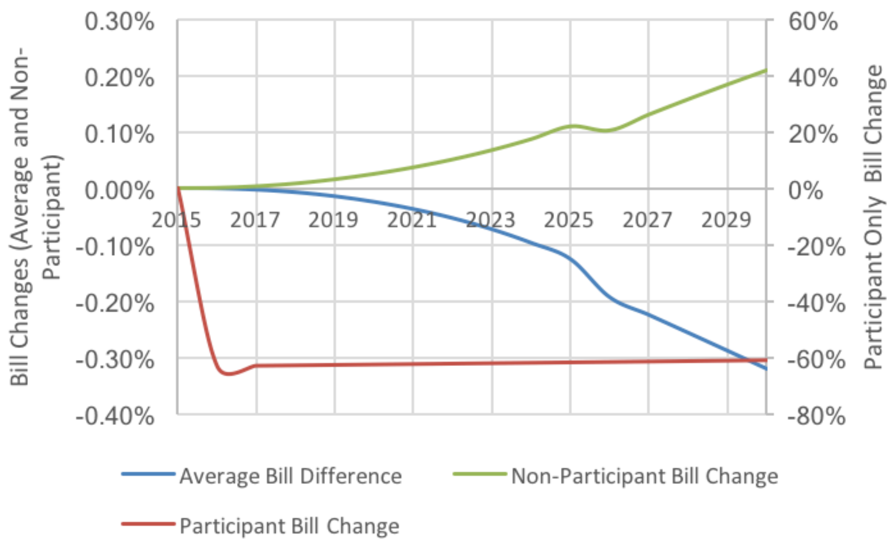

Figure 3-10 Impact of NEM on Residential Customer Bills, 2016-2030

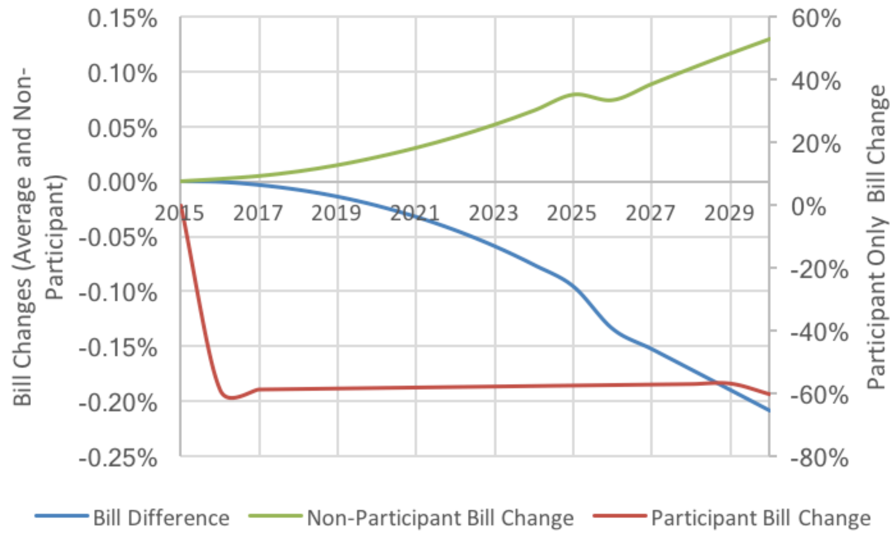

Figure 3-11 Impact of RNR on Residential Customer Bills, 2016-2030

Overall, when compared across all residential customer bills, our analysis shows that the impacts of the VOST and NEM programs result in an overall reduction in average customer bills.

3.7 Conclusions

In this chapter, we built on the research conducted in Chapter 2, which established a range of VOST for distributed solar in Georgia Power Company's territory and estimated the potential cost shift of three VOST estimates — 7.5c/kWh, 14.4 c/kWh, and 17.2 c/kWh — as well as NEM and a continued RNR tariff. GT-DSM was used to evaluate the impacts of each of these compensation mechanisms, specifically on rate and bill impacts.

Throughout the country regulators are faced with the task of transitioning the electricity system, determining the best policies to grow technological innovations, and transition the incumbent utility's business model. DGPV is one niche technology that represents a pathway for sustainable transition and the policies of NEM and increasingly VOST are being used to develop DGPV. As the adoption of DGPV grows, incumbent utilities have used many strategies to slow the growth, as proliferation of DGPV fundamentally challenges the utility business model- one which is currently locked-in with regulatory policies. Incumbent utilities argue that any compensation for exported distributed energy will inevitably produce a cost shift from solar customers to non-solar customers. Despite such consistent claims, very few studies have examined the legitimacy of the cost-shift argument.

From our analysis, it is clear that under the current business model, growth in DGPV results in lost revenues to the utility and to recover those lost revenues (and maintain their guaranteed profit margin) utilities will increase costs on non-solar customers. However, it is also clear that under reasonable market conditions, the margin of cost increase on non-solar customers from the use of VOST and NEM is small, less than 1% of the average customer's bill, in terms of monetary impact. If Georgia regulators were to adopt a VOST above retail rate or NEM, growth in the state's DGPV market would increase substantially over the next ten years. Moreover, despite this growth, the analysis found that the monetary impact to non-solar customers was negligible. Additionally, under NEM and all estimates of VOST, GPC will witness sizable savings from reduced variable production costs. Even under an above retail-rate VOST has minimal impacts on non-participants and would be indiscernible in the year-to-year variation in electricity prices. However, these calculations were done to examine an impact when the total capacity of the DGPV market remained under 12 MW. While this may be a large expansion from the current residential Georgia market, it is still less than 1% of GPC's total generation portfolio. If DGPV were to grow to meet a sizable portion of Georgia's demand, under the current regulatory structure, the impact on non-solar customers could be far more substantial. However, even a recent study by Johnson et al (2017) showed that DGPV could grow to be 5% of generation in New Jersey and non-participant bills would increase by 2% or less.

This underscores the need for more analysis on the impacts of niche policies on the incumbent regimes and society at large. There is no consensus within the policy literature, or among policymakers, as to what is a reasonable impact of policies which support the adoption of renewable energy. Federal investments into the research and development of renewable technologies are supported by tax-payer dollars and justified as an investment in energy security. However, whether society should pay for the advancement of niche technologies through taxes or through other market mechanisms, such as NEM or VOST, is a question the policy literatures have not tackled. Understanding what is a reasonable cost to transition our energy system, must also be paired with a deeper understanding of the benefits. More analytical work is needed to truly understand the actual impacts of niche policies and separate legitimate concerns from the political strategies of the incumbent regime. By building the analytical literature, policy makers can begin to form hypotheses on what types of market mechanisms will best facilitate the sustainable transition.

Returning to my analysis of GPC, this research also underscores the need for regulators to assess the legitimacy of utility's resistance strategies for their technical merit. From my analysis, it is clear that Georgia regulators could institute NEM or VOST policies with the goal of growing the DGPV market without burdening non-solar customers. Meaning that these policies could both simultaneously grow the adoption of niche innovations while giving regulators the runway necessary to transition the incumbent utility business model that inherently clashes with the growth of DGPV.

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3.9 Appendix

3.9.1 GT-DSM Outputs for VOST-7.5 c/kWh

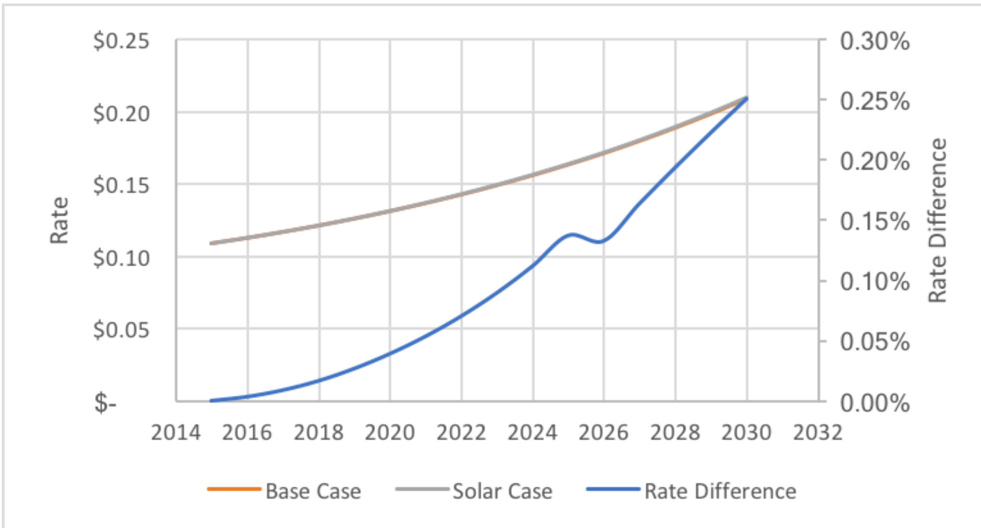

Figure 3-12 Rate Impacts of a 7.5c/kWh VOST

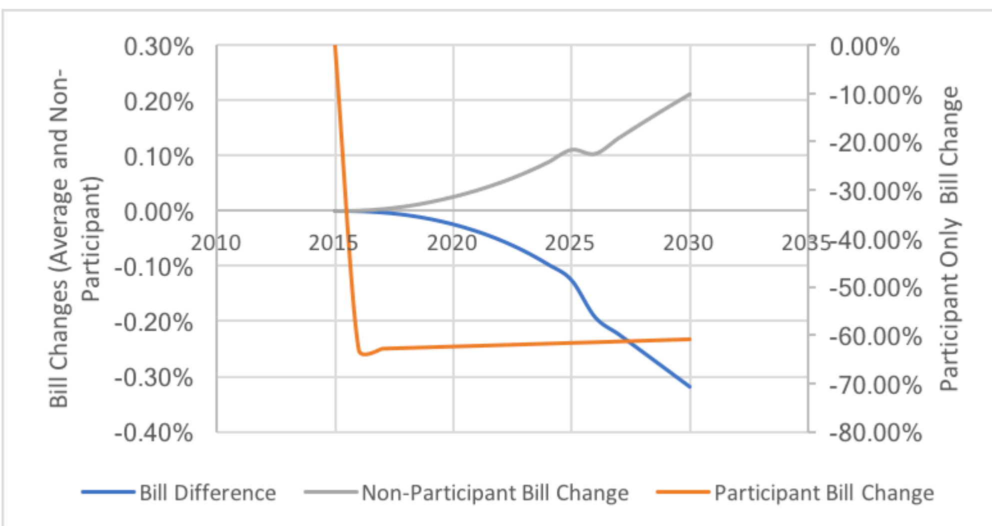

Figure 3-13 Bill Impacts of a 7.5c/kWh VOST

Table 3-4 Customer Impacts of a 7.5c/kWh VOST

Avg Difference in Bill	%/month	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.02%	-0.03%	-0.04%	-0.06%	-0.08%	-0.11%	-0.16%	-0.19%	-0.22%	-0.24%	-0.27%
Avg Difference in Participant Bill	"	0.00%	-60.16%	-69.52%	-69.08%	-68.63%	-68.19%	-67.76%	-67.32%	-66.88%	-66.44%	-66.01%	-65.59%	-65.37%	-65.15%	-64.95%	-64.77%
Avg Difference in Non-Participant Bill	"	0.00%	0.00%	0.00%	0.01%	0.02%	0.02%	0.04%	0.05%	0.06%	0.08%	0.10%	0.09%	0.12%	0.14%	0.16%	0.18%
Annual Bill Change	$	$-	$(7,624)	$(33,875)	$(127,013)	$(276,273)	$(484,242)	$(748,827)	$(1,072,411)	$(1,460,169)	$(1,917,969)	$(2,451,843)	$(3,686,364)	$(4,250,373)	$(4,809,827)	$(5,364,812)	$(5,915,412)

Table 3-5 Customer Impacts of a 7.5c/kWh VOST

Rate Difference	%	0.00%	0.00%	0.01%	0.02%	0.03%	0.04%	0.05%	0.07%	0.08%	0.10%	0.13%	0.12%	0.15%	0.18%	0.20%	0.22%
Rate Comparison																	
Base Case	$/kWh	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21
PV Case	"	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21

Table 3-6 Utility Impacts of a 7.5c/kWh VOST

Costs - Base	$	$4,573,362,268	$4,814,035,023	$5,104,075,936	$5,416,223,647	$5,752,095,689	$6,113,430,131	$6,502,094,515	$6,920,095,470	$7,369,589,023	$7,852,891,699	$8,372,492,425	$8,931,065,330	$9,531,483,500	$10,176,833,742	$10,870,432,459	$11,615,842,699
Variables Cost - Base	"	$3,244,800,000	$3,455,996,873	$3,713,869,278	$3,990,987,393	$4,288,787,895	$4,608,814,731	$4,952,727,132	$5,322,308,218	$5,719,474,253	$6,146,284,589	$6,604,952,353	$7,097,855,928	$7,627,551,303	$8,196,785,333	$8,808,509,995	$9,465,897,711
Fixed Cost - Base	"	$1,328,562,268	$1,358,038,150	$1,390,206,658	$1,425,236,254	$1,463,307,794	$1,504,615,399	$1,549,367,383	$1,597,787,251	$1,650,114,770	$1,706,607,110	$1,767,540,072	$1,833,209,402	$1,903,932,197	$1,980,048,409	$2,061,922,464	$2,149,944,988

Table 3-7 Utility Impacts of a 7.5c/kWh VOST

Costs - w/PV	$	$4,544,595,583	$4,814,000,431	$5,103,993,685	$5,416,013,962	$5,751,678,386	$6,112,708,007	$6,500,953,085	$6,918,395,393	$7,367,158,808	$7,849,521,071	$8,367,925,221	$8,924,992,284	$9,523,666,835	$10,167,063,545	$10,858,478,113	$11,601,451,024
Variables Cost - w/PV	"	$3,216,033,315	$3,455,958,792	$3,713,743,075	$3,990,708,472	$4,288,273,233	$4,607,967,834	$4,951,432,703	$5,320,424,098	$5,716,825,712	$6,142,657,747	$6,600,087,348	$7,091,439,953	$7,619,393,425	$8,186,675,628	$8,796,217,838	$9,451,169,915
Fixed Cost - w/PV	"	$1,328,562,268	$1,358,041,640	$1,390,250,609	$1,425,305,491	$1,463,405,153	$1,504,740,173	$1,549,520,382	$1,597,971,295	$1,650,333,096	$1,706,863,324	$1,767,837,873	$1,833,552,331	$1,904,273,411	$1,980,387,917	$2,062,260,275	$2,150,281,110

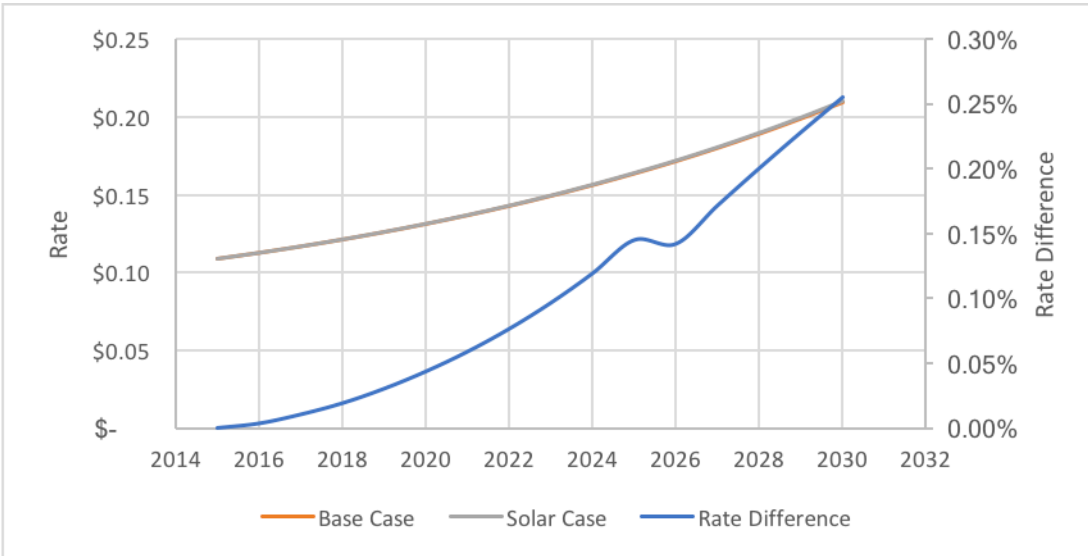

Figure 3-14 Rate Impacts of a 14.4 c/kWh VOST

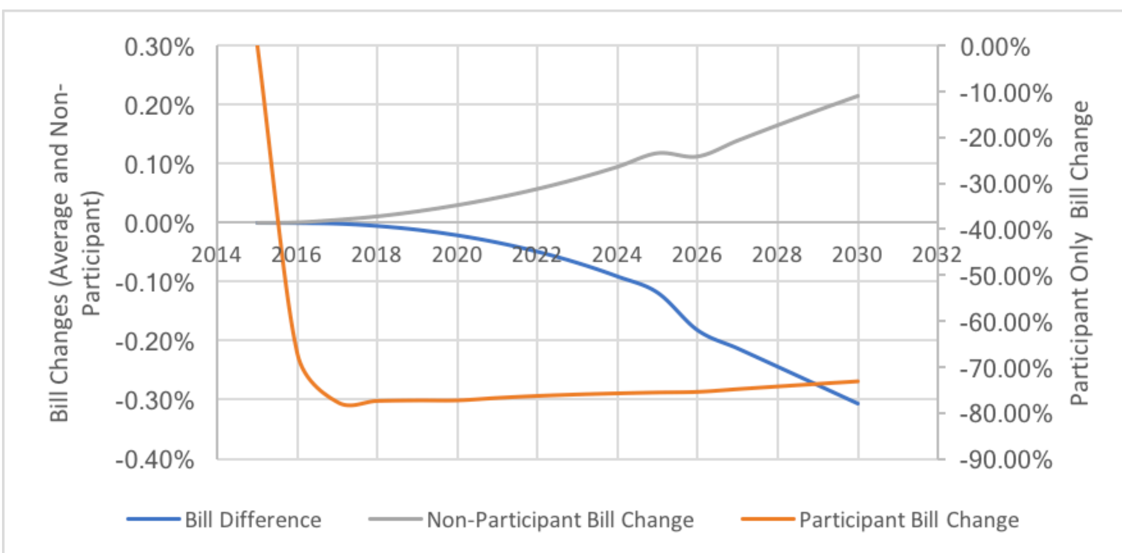

Figure 3-15 Bill Impacts of a 14.4 c/kWh VOST

Table 3-8 Customer Impacts of a 14.4c/kWh VOST

Avg Difference in Bill	%/month	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.02%	-0.03%	-0.05%	-0.07%	-0.09%	-0.12%	-0.18%	-0.21%	-0.24%	-0.28%	-0.31%
Avg Difference in Participant Bill	"	0.00%	-67.20%	-77.76%	-77.50%	-77.38%	-77.38%	-76.84%	-76.41%	-76.09%	-75.85%	-75.66%	-75.52%	-74.92%	-74.34%	-73.77%	-73.22%
Avg Difference in Non-Participant Bill	"	0.00%	0.00%	0.00%	0.01%	0.02%	0.03%	0.04%	0.06%	0.07%	0.09%	0.12%	0.11%	0.14%	0.16%	0.19%	0.21%
Annual Bill Change	$	$-	$(8,559)	$(37,926)	$(141,791)	$(308,839)	$(542,944)	$(841,744)	$(1,207,287)	$(1,646,242)	$(2,166,325)	$(2,775,478)	$(4,204,391)	$(4,845,172)	$(5,477,652)	$(6,101,989)	$(6,718,336)

Table 3-9 Customer Impacts of a 14.4c/kWh VOST

Rate Difference	%	0.00%	0.00%	0.01%	0.02%	0.03%	0.04%	0.06%	0.08%	0.10%	0.12%	0.14%	0.14%	0.17%	0.20%	0.23%	0.25%
Rate Comparison																	
Base Case	$/kWh	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21
PV Case	"	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21

Table 3-10 Utility Impacts of a 14.4c/kWh VOST

	$	$4,573,362,268	$4,814,035,023	$5,104,075,936	$5,416,223,647	$5,752,095,689	$6,113,430,131	$6,502,094,515	$6,920,095,470	$7,369,589,023	$7,852,891,699	$8,372,492,425	$8,931,065,330	$9,531,483,500	$10,176,833,742	$10,870,432,459	$11,615,842,699
Variables Cost - Base	"	$3,244,800,000	$3,455,996,873	$3,713,869,278	$3,990,987,393	$4,288,787,895	$4,608,814,731	$4,952,727,132	$5,322,308,218	$5,719,474,253	$6,146,284,589	$6,604,952,353	$7,097,855,928	$7,627,551,303	$8,196,785,333	$8,808,509,995	$9,465,897,711
Fixed Cost - Base	"	$1,328,562,268	$1,358,038,150	$1,390,206,658	$1,425,236,254	$1,463,307,794	$1,504,615,399	$1,549,367,383	$1,597,787,251	$1,650,114,770	$1,706,607,110	$1,767,540,072	$1,833,209,402	$1,903,932,197	$1,980,048,409	$2,061,922,464	$2,149,944,988

Table 3-11 Utility Impacts of a 14.4c/kWh VOST

	$	$4,544,595,583	$4,813,996,318	$5,103,983,434	$5,415,988,085	$5,751,626,358	$6,112,616,027	$6,500,805,451	$6,918,173,524	$7,366,838,729	$7,849,071,819	$8,367,307,303	$8,924,155,852	$9,522,581,289	$10,165,706,539	$10,856,825,864	$11,599,478,241
Variables Cost - w/PV	"	$3,216,033,315	$3,455,954,314	$3,713,728,006	$3,990,674,629	$4,288,209,255	$4,607,859,380	$4,951,264,616	$5,320,177,073	$5,716,474,772	$6,142,170,789	$6,599,423,679	$7,090,548,417	$7,618,253,050	$8,185,264,068	$8,794,511,308	$9,449,143,122
Fixed Cost - w/PV	"	$1,328,562,268	$1,358,042,004	$1,390,255,428	$1,425,313,456	$1,463,417,103	$1,504,756,648	$1,549,540,835	$1,597,996,451	$1,650,363,958	$1,706,901,030	$1,767,883,624	$1,833,607,435	$1,904,328,239	$1,980,442,471	$2,062,314,556	$2,150,335,119

3.9.2 *GT-DSM Outputs for VOST-17.2 c/kWh*

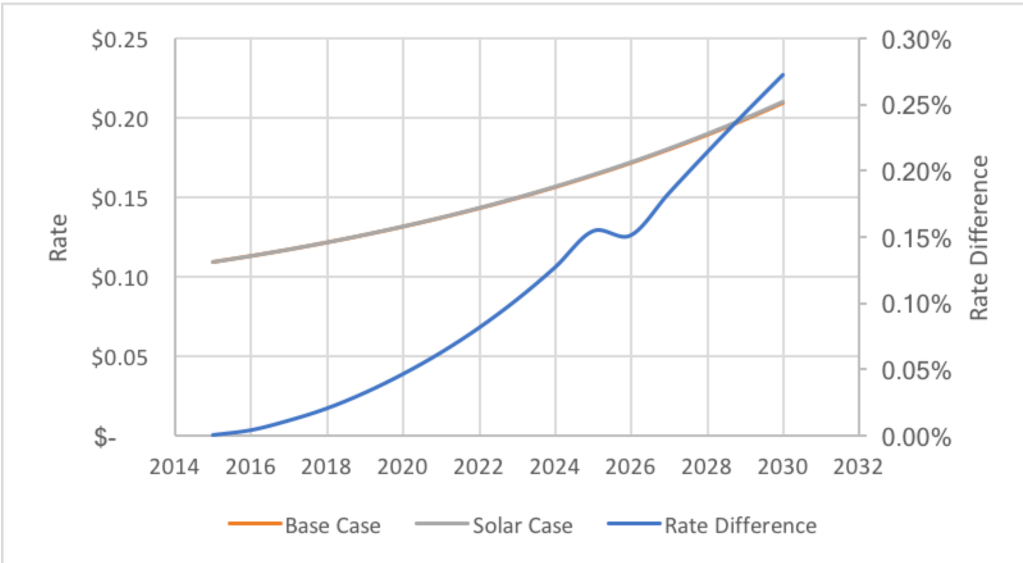

Figure 3-16 Rate Impacts of a 17.2 c/kWh VOST

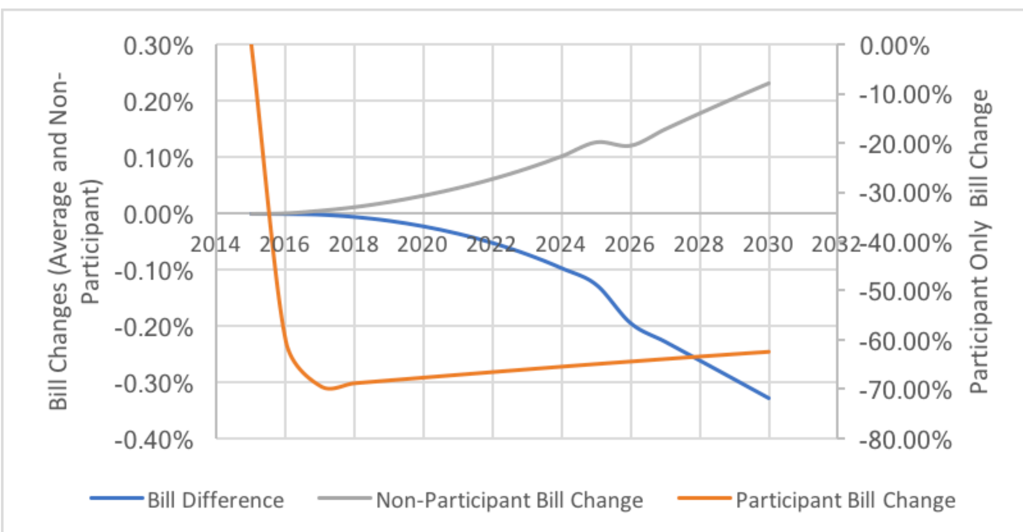

Figure 3-17 Bill Impacts of a 17.2 c/kWh VOST

Table 3-12 Customer Impacts of a 17.2 c/kWh VOST

Avg Difference in Bill	%/month	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.02%	-0.04%	-0.05%	-0.07%	-0.10%	-0.13%	-0.20%	-0.23%	-0.26%	-0.30%	-0.33%
Avg Difference in Participant Bill	"	0.00%	-60.13%	-69.25%	-68.68%	-68.10%	-67.54%	-66.97%	-66.41%	-65.86%	-65.32%	-64.78%	-64.27%	-63.76%	-63.26%	-62.77%	-62.30%
Avg Difference in Non-Participant Bill	"	0.00%	0.00%	0.01%	0.01%	0.02%	0.03%	0.05%	0.06%	0.08%	0.10%	0.13%	0.12%	0.15%	0.18%	0.21%	0.23%
Annual Bill Change	$	$-	$(8,999)	$(39,869)	$(149,345)	$(325,863)	$(574,112)	$(891,679)	$(1,280,550)	$(1,748,247)	$(2,303,569)	$(2,955,499)	$(4,488,802)	$(5,176,401)	$(5,855,093)	$(6,525,047)	$(7,186,426)

Table 3-13 Customer Impacts of a 17.2 c/kWh VOST

Rate Difference	%	0.00%	0.00%	0.01%	0.02%	0.03%	0.05%	0.06%	0.08%	0.10%	0.13%	0.15%	0.15%	0.18%	0.21%	0.24%	0.27%
Rate Comparison																	
Base Case	$/kWh	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21
PV Case	"	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21

Table 3-14 Utility Impacts of a 17.2 c/kWh VOST

Costs - Base	$	$4,573,362,268	$4,814,035,023	$5,104,075,936	$5,416,223,647	$5,752,095,689	$6,113,430,131	$6,502,094,515	$6,920,095,470	$7,369,589,023	$7,852,891,699	$8,372,492,425	$8,931,065,330	$9,531,483,500	$10,176,833,742	$10,870,432,459	$11,615,842,699
Variables Cost - Base	"	$3,244,800,000	$3,455,996,873	$3,713,869,278	$3,990,987,393	$4,288,787,895	$4,608,814,731	$4,952,727,132	$5,322,308,218	$5,719,474,253	$6,146,284,589	$6,604,952,353	$7,097,855,928	$7,627,551,303	$8,196,785,333	$8,808,509,995	$9,465,897,711
Fixed Cost - Base	"	$1,328,562,268	$1,358,038,150	$1,390,206,658	$1,425,236,254	$1,463,307,794	$1,504,615,399	$1,549,367,383	$1,597,787,251	$1,650,114,770	$1,706,607,110	$1,767,540,072	$1,833,209,402	$1,903,932,197	$1,980,048,409	$2,061,922,464	$2,149,944,988

Table 3-15 Utility Impacts of a 17.2 c/kWh VOST

	$	$4,544,595,583	$4,813,994,329	$5,103,978,574	$5,415,975,380	$5,751,600,238	$6,112,569,013	$6,500,728,883	$6,918,056,967	$7,366,668,677	$7,848,830,735	$8,366,972,813	$8,923,699,566	$9,521,982,930	$10,164,949,395	$10,855,891,621	$11,598,346,848
Variables Cost - w/EE	"	$3,216,033,315	$3,455,952,128	$3,713,720,527	$3,990,657,623	$4,288,176,699	$4,607,803,533	$4,951,177,111	$5,320,047,072	$5,716,288,291	$6,141,909,672	$6,599,064,989	$7,090,063,044	$7,617,625,750	$8,184,478,128	$8,793,548,412	$9,447,983,220
Fixed Cost - w/EE	"	$1,328,562,268	$1,358,042,202	$1,390,258,046	$1,425,317,757	$1,463,423,538	$1,504,765,479	$1,549,551,772	$1,598,009,895	$1,650,380,385	$1,706,921,063	$1,767,907,824	$1,833,636,522	$1,904,357,180	$1,980,471,268	$2,062,343,209	$2,150,363,629

3.9.3 GT-DSM Outputs for RNR-4 c/kWh

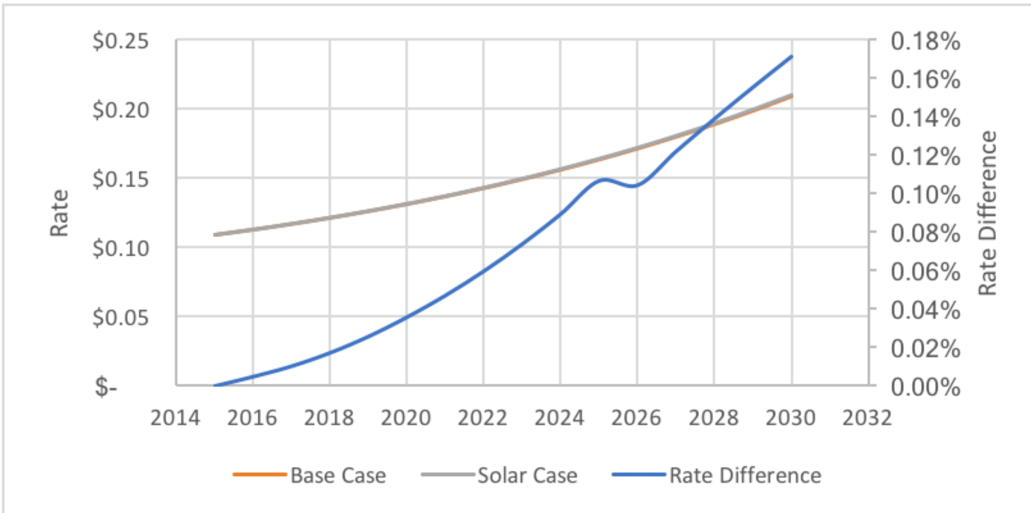

Figure 3-18 Rate Impacts of a RNR

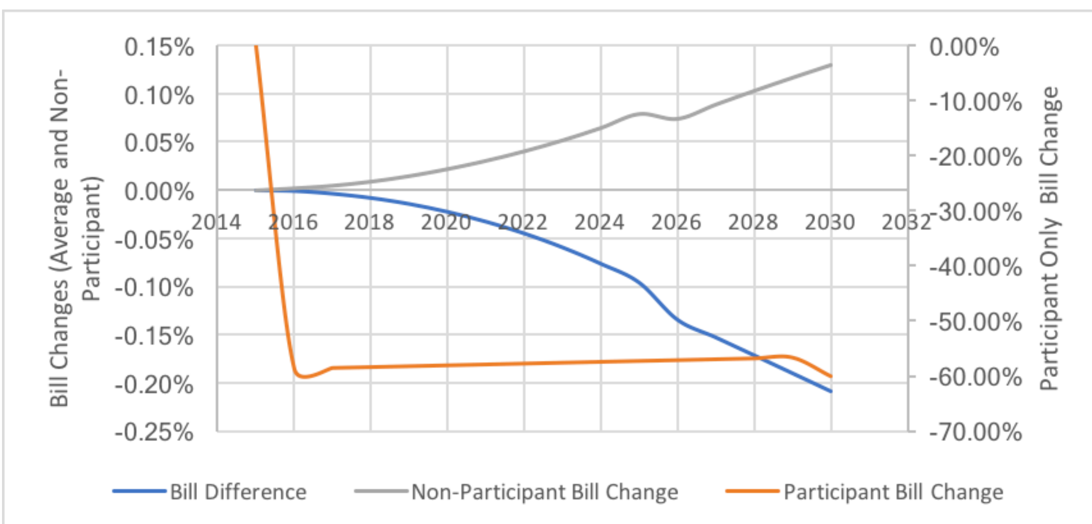

Figure 3-19 Bill Impacts of a RNR

Table 3-16 Customer Impacts of RNR

Avg Difference in Bill	%/month	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.02%	-0.03%	-0.04%	-0.06%	-0.08%	-0.10%	-0.13%	-0.15%	-0.17%	-0.19%	-0.21%
Avg Difference in Participant Bill	"	0.00%	-58.81%	-58.66%	-58.50%	-58.34%	-58.18%	-58.02%	-57.86%	-57.70%	-57.54%	-57.38%	-57.23%	-57.08%	-56.92%	-56.76%	-60.16%
Avg Difference in Non-Participant Bill	"	0.00%	0.00%	0.00%	0.01%	0.01%	0.02%	0.03%	0.04%	0.05%	0.06%	0.08%	0.07%	0.09%	0.10%	0.12%	0.13%
Annual Bill Change	$	$-	$(15,302)	$(92,681)	$(208,833)	$(366,617)	$(568,281)	$(811,077)	$(1,095,630)	$(1,424,869)	$(1,802,015)	$(2,229,795)	$(3,079,918)	$(3,452,759)	$(3,821,217)	$(4,185,345)	$(4,545,200)

Table 3-17 Utility Impacts of RNR

	$	$4,573,362,268	$4,814,035,023	$5,104,075,936	$5,416,223,647	$5,752,095,689	$6,113,430,131	$6,502,094,515	$6,920,095,470	$7,369,589,023	$7,852,891,699	$8,372,492,425	$8,931,065,330	$9,531,483,500	$10,176,833,742	$10,870,432,459	$11,615,842,699
Variables Cost - Base	"	$3,244,800,000	$3,455,996,873	$3,713,869,278	$3,990,987,393	$4,288,787,895	$4,608,814,731	$4,952,727,132	$5,322,308,218	$5,719,474,253	$6,146,284,589	$6,604,952,353	$7,097,855,928	$7,627,551,303	$8,196,785,333	$8,808,509,995	$9,465,897,711
Fixed Cost - Base	"	$1,328,562,268	$1,358,038,150	$1,390,206,658	$1,425,236,254	$1,463,307,794	$1,504,615,399	$1,549,367,383	$1,597,787,251	$1,650,114,770	$1,706,607,110	$1,767,540,072	$1,833,209,402	$1,903,932,197	$1,980,048,409	$2,061,922,464	$2,149,944,988

Table 3-18 Utility Impacts of RNR

Costs - w/PV		$	$4,544,595,583	$4,813,976,442	$5,103,914,907	$5,415,906,243	$5,751,553,687	$6,112,580,756	$6,500,844,805	$6,918,333,341	$7,367,179,160	$7,849,671,375	$8,368,267,797	$8,925,715,439	$9,524,877,528	$10,168,828,419	$10,860,870,981	$11,604,553,552
	Variables Cost - w/PV	"	$3,216,033,315	$3,455,936,544	$3,713,705,556	$3,990,666,274	$4,288,241,041	$4,607,959,306	$4,951,470,253	$5,320,537,713	$5,717,054,698	$6,143,053,144	$6,600,715,068	$7,092,493,442	$7,620,932,800	$8,188,767,542	$8,798,936,111	$9,454,596,220
	Fixed Cost - w/PV	"	$1,328,562,268	$1,358,039,898	$1,390,209,351	$1,425,239,969	$1,463,312,647	$1,504,621,450	$1,549,374,552	$1,597,795,629	$1,650,124,462	$1,706,618,232	$1,767,552,730	$1,833,221,997	$1,903,944,728	$1,980,060,877	$2,061,934,870	$2,149,957,332

3.9.4 GT-DSM Outputs for NEM

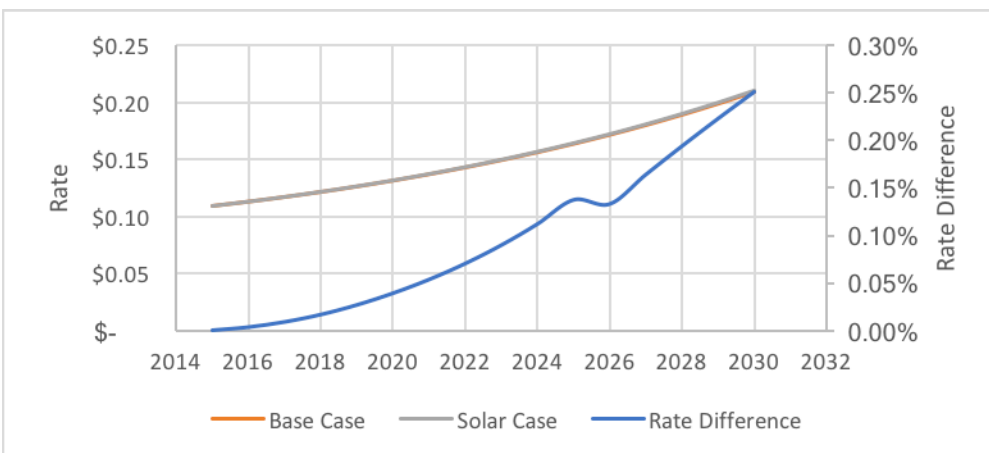

Figure 3-20 Rate Impacts of a NEM

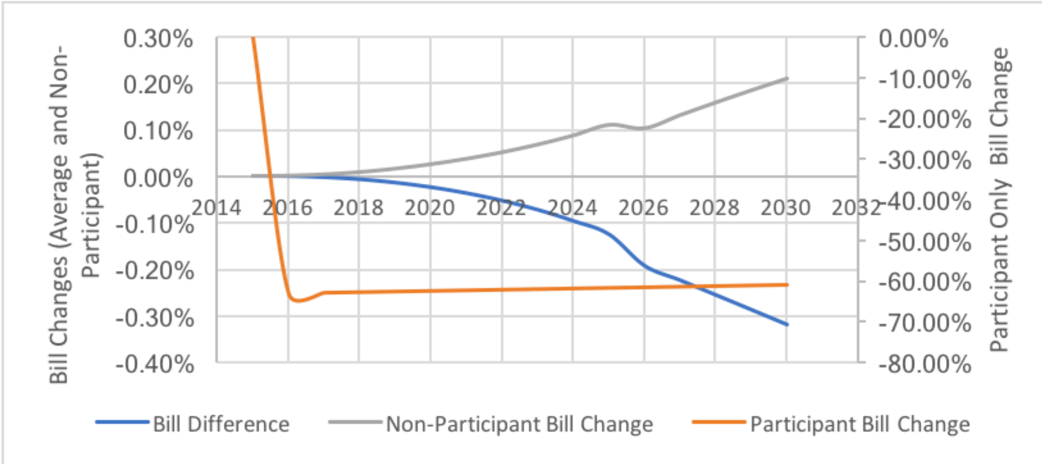

Figure 3-21 Bill Impacts of a NEM

Table 3-19 Customer Impacts of NEM

Avg Difference in Bill	%/month	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.02%	-0.04%	-0.05%	-0.07%	-0.10%	-0.13%	-0.19%	-0.22%	-0.26%	-0.29%	-0.32%
Avg Difference in Participant Bill	"	0.00%	-63.04%	-62.90%	-62.75%	-62.60%	-62.45%	-62.30%	-62.15%	-62.00%	-61.85%	-61.70%	-61.56%	-61.41%	-61.25%	-61.10%	-60.95%
Avg Difference in Non-Participant Bill	"	0.00%	0.00%	0.00%	0.01%	0.02%	0.03%	0.04%	0.05%	0.07%	0.09%	0.11%	0.10%	0.13%	0.16%	0.18%	0.21%
Annual Bill Change	$	$-	$(11,511)	$(74,606)	$(193,688)	$(374,451)	$(618,754)	$(925,735)	$(1,300,656)	$(1,751,991)	$(2,289,827)	$(2,924,057)	$(4,423,793)	$(5,068,978)	$(5,706,590)	$(6,336,766)	$(6,959,578)

Table 3-20 Utility Impacts of NEM

		$	$4,573,362,268	$4,814,035,023	$5,104,075,936	$5,416,223,647	$5,752,095,689	$6,113,430,131	$6,502,094,515	$6,920,095,470	$7,369,589,023	$7,852,891,699	$8,372,492,425	$8,931,065,330	$9,531,483,500	$10,176,833,742	$10,870,432,459	$11,615,842,699
Variables Cost - Base		"	$3,244,800,000	$3,455,996,873	$3,713,869,278	$3,990,987,393	$4,288,787,895	$4,608,814,731	$4,952,727,132	$5,322,308,218	$5,719,474,253	$6,146,284,589	$6,604,952,353	$7,097,855,928	$7,627,551,303	$8,196,785,333	$8,808,509,995	$9,465,897,711
Fixed Cost - Base		"	$1,328,562,268	$1,358,038,150	$1,390,206,658	$1,425,236,254	$1,463,307,794	$1,504,615,399	$1,549,367,383	$1,597,787,251	$1,650,114,770	$1,706,607,110	$1,767,540,072	$1,833,209,402	$1,903,932,197	$1,980,048,409	$2,061,922,464	$2,149,944,988

Table 3-21 Utility Impacts of NEM

Costs - w/PV		$	$4,544,595,583	$4,813,993,671	$5,103,938,490	$5,415,919,255	$5,751,531,887	$6,112,497,451	$6,500,663,003	$6,918,002,645	$7,366,631,549	$7,848,815,534	$8,366,983,735	$8,923,740,342	$9,522,125,253	$10,165,204,430	$10,856,271,558	$11,598,865,014
	Variables Cost - w/PV	"	$3,216,033,315	$3,455,955,521	$3,713,731,832	$3,990,683,002	$4,288,224,093	$4,607,882,051	$4,951,295,620	$5,320,215,394	$5,716,516,779	$6,142,208,425	$6,599,443,663	$7,090,530,940	$7,618,193,056	$8,185,156,021	$8,794,349,094	$9,448,920,026
	Fixed Cost - w/PV	"	$1,328,562,268	$1,358,038,150	$1,390,206,658	$1,425,236,254	$1,463,307,794	$1,504,615,399	$1,549,367,383	$1,597,787,251	$1,650,114,770	$1,706,607,110	$1,767,540,072	$1,833,209,402	$1,903,932,197	$1,980,048,409	$2,061,922,464	$2,149,944,988

CHAPTER 4. INNOVATIONS IN LOCAL GOVERNANCE- THE EVOLVING ROLE OF THIRD-SECTOR ACTORS IN MUNICIPAL ENERGY POLICY

4.1 Introduction

Since the 1990s, there has been a substantial growth in the innovation and variation of local and regional policy responses to the issues of climate change, clean energy development, and greater sustainability goals (Broto and Bulkeley, 2013). In the United States, the inconsistency in a federal energy policy and a continued trend of devolution has pushed cities to the forefront space of leading the country towards a sustainable transition of its energy system. While the transition literature has historically overlooked the role of cities, there is a growing recognition of the need to examine cities and regions as important arenas to understand the struggles of developing sociotechnical regimes, the agency of actors, and how cities collectively at the national and international level can transcend the established levels of governance and create additional arenas to challenge the incumbent regime (Bulkeley and Betsill, 2005).

While it is unlikely that the actions of a single city can produce an energy system transition, it may be that in concert with other cities there is a great opportunity to develop and transition niche innovations. One way in which cities are increasingly networked is through the strategic engagement of ‘third- sector institutions’. According to Clark (2017) third-sector institutions are non- governmental organizations or intermediaries that are “operating within private market spaces to expand the provisioning of public services and collective goods or enhance the efficient delivery of new or existing services beyond the boundaries of local government (pg. 812)."

Increasingly, third-sector institutions include a network of national or international intermediaries with the specific purpose of influencing the policies of local government. Through a practice that Clark (2017) refers to as 'strategic capacity seeding' the large Intermediaries utilize philanthropic funding to seed new capacity into local cities through providing technical assistance and at times placing professional staff in city governments. These investments while not explicitly attached to a specific policy agenda, are deeply connected to the development of niche technologies and innovations through market- driven approaches, with the goal of achieving a shared vision of the new energy regime- such as improved resilience, sustainability, and efficiency.

From a sociotechnical perspective, these third-sector institutions can be viewed as both niche actors and intermediary actors. Niche actors are individual and collective participants that are engaging in purposive actions in an attempt to prevent or generate change (Bos, 2013). According to Geels (2012), niche actors create a starting point for a systemic change and facilitate sustainable transitions, therefore greater attention needs to be given to the actions of niche actors as the choices and decisions of niche actors will ultimately shape the political contours of the next regime. Foxon (2010) finds that niche actors work on radical innovations and are involved in several processes, such as knowledge development and diffusion, articulation of visions, entrepreneurial activities, market formation, guidance of search activities, mobilization of resources, creation of legitimacy and the overcoming of resistance to change. However, a number of authors have argued that a condition for a successful niche transition depends on changes in government policy and support (Hielscher et al, 2011; Geels, 2012). Arguably, this underscores niche actors' dependency on decisions made by policymakers and the government but it doesn't limit the contours of policy innovation coming from niche actors to the existing public services model.

Intermediaries are actors that often work at all levels and can work irrespective of government policy or support (Fischer, 2016). In the context of sustainable energy transitions. intermediaries are organizations and networks that build links between specific community energy groups, and which exist to share experience, good practice, expertise and advice. In some cases, intermediaries also act as a voice for community energy by providing evidence and advocacy to policy-makers. In many ways intermediaries are akin to policy entrepreneurs which serve to negotiate the translation between niche and regime (Smith, 2005).

As the instances of third-sector institutions' seeding' the city- scale adoption of energy policies grows, it is important to understand how and where these actors are shaping the policy process, as the actions they take, and the institutions they form will have implications for energy transitions at the national level. In this chapter, I build on the work done by Clark (2017) an explore an instance of 'strategic seeding in cities.' First, I use the MLP framework as a heuristic to organize the niche-regime relationship of the current energy regime, identify the niche innovation that third-sector intermediary actors are working to develop, and the sociotechnical landscape that impacts the dynamics of transition. My focus in this chapter is on the strategies and impacts of intermediary actors in sustainable transitions in networked cities. After characterizing where these third-sector actors fit within the sociotechnical landscape, I turn to understanding the impacts of 'strategic seeding' on the institutions of local governments and the role of the public in these third-sector actors led movements toward sustainable transition. I build my hypotheses on the impacts of strategic seeding in cities from multiple literatures examining the innovation in policy at the city-level and the role of Intermediaries in the policy process. I then test these hypotheses with a case study on the City Energy Project in Atlanta, GA.

The ability for a single city's to qualitatively change the national energy regime is unlikely. However, to the degree that third-sector actors are systematically changing the behavior and capacity of the institutions in cities throughout the country and building momentum and support for regime change, strategic capacity seeding represents a new avenue for sustainable transition and one in which researchers attempting to understand the dynamics of sociotechnical transitions need to account for. Of course, it could also be the case that strategic seeding is not fundamentally changing the institutions of the regime but merely producing incremental change. In my conclusion, I reflect on these sentiments and use the case study of Atlanta to draw some inferences on the potential for strategic seeding to produce a regime change and where the research needs to head in the future.

4.2 Analytical Framework: Defining the Regime, Niche, Sociotechnical Landscape, and understanding Third-Sectors Actors' within the Multi-Level Perspective (MLP)

The MLP framework serves as a heuristic to diagram the social, technical, economic, environmental, and political dynamics of a sustainable transition. The MLP framework distinguishes between three analytical levels with increasing temporal stability. The first is the niche. The niche is the level at which innovation occurs and is characterized by a flexibility and uncertainty. The regime is the presiding stable set of practices, technologies or rules that have been legitimized through institutional and technological lock-in. The sociotechnical landscape contains the slow-moving societal processes that provide the context for regime stability or change. Transitions, defined as regime change, occur through the interplay between niche innovation, internal regime change and landscape factors. It is important to recognize that these levels themselves do not have agency, rather, actors working in each level (either to support or change the regime) are the agents of change.

Applying the MLP to the electricity system in the United States, the regime consists of three interlinked dimensions (Geels, 2005): (a) network of actors and social groups; in the electricity regime important actors are utilities, regulatory and legislative policy actors, large commercial and industrial users, and households; (b) formal, normative and cognitive rules that guide the activities of actors; examples include regulations, building code standards, utility business models, and user laws; examples of cognitive rules are belief systems, problem agenda's, and guiding (often economic) principles; examples of normative rules are role relationships and behavioral norms, (c) material and technical elements; in the case of electricity, these include resources, grid investments, power plants, etc.

According to Verbong and Geels (2007) electricity regimes are characterized by path dependence, resulting from stabilizing mechanisms on the three dimensions (a) incumbent actors (utilities or large resource suppliers and users)have vested interests and supportive social networks (b) while regulations and standards stabilize regimes (i.e low electricity rates for high consumers of energy) , the cognitive routines of users blind actors to developments outside their focus (i.e people don't realize or care their appliances are wasting electricity) ; (c) existing machines and infrastructures (i.e power plants) stabilize regimes through sunk investments and technical complementarities between components (Unruh, 2000) For a further explanation in the current U.S electricity regime see Chapter 2.

The niche is the micro level where innovations emerge. These can be small market niches or technological innovations. In the context of the electricity system, niche innovations include everything from technological innovations such as distributed solar photovoltaics, to carbon markets, to LED light bulbs. A key challenge in enabling sustainable transitions towards new forms of decarbonized and highly energy-efficient consumption is determining how to change current energy-intensive and fossil fuel-based consumption patterns. Niche actors work to develop innovations and change the behaviors of users through multiple policy spaces so technological innovations can to be incorporated or overthrow the regime. Unlike the regime, there are few if any formal rules to niche level, rather the niche is characterized by experimentation. Compared with regimes, the actors in niches are few, and their interrelations sparse. In order for niches to transition, actors must develop supportive networks and policies for promotion. For the purpose of this research, the niche innovation is energy efficiency and the supporting actors are third-sector actors working to establish policies in cities that support the greater adoption of energy efficient buildings.

The socio-technical landscape then represents the socio-economic, cultural, and environmental context in which actors at the niche and regime level are acting. In the context of our energy system, the landscape represents the national and international trends, macro-economic patterns, the totality of infrastructure, and political cultures that are even beyond the direct control of the regime and niche (Grin et al. 2010). Such examples include concerns over climate change, energy access, resource scarcity, migration, wars, and economic development patterns. The dynamics of the landscape level, shape the dominant economic and political discourses, and influence the patterns of behavior actors within the regime and outside the regime. Figure 4.1 outlines the relationships between these levels.

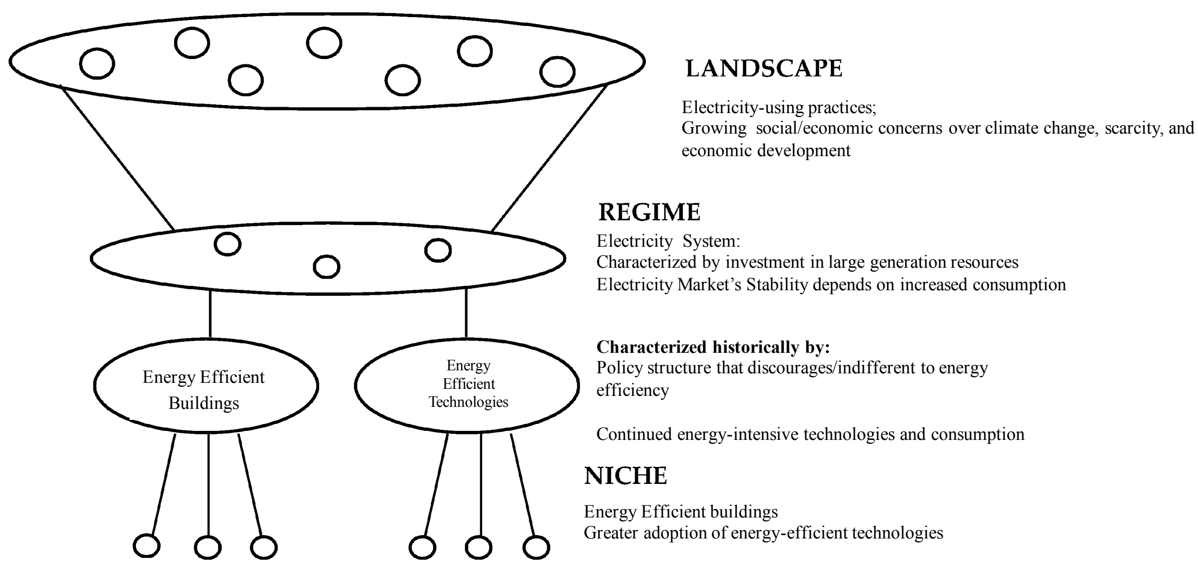

Figure 4-1 The multi-level perspective (landscape, regime, niche) and corresponding dynamics in the context of the U.S Energy System

Sustainable transitions are large in scale and long in term and constitute shifts from one socio-technical regime and system to another. These shifts involve interactions between landscapes, regimes and niche dynamics. In the MLP framework, transitions can be conceptualized as a sequence of three phases:

- Start-up. The internal problems of the regime are magnified by landscape pressure, creating opportunities for innovation that, for the time being, emerge and mature in niches.
- Acceleration. Niche innovations enter the mainstream market and start to compete with the incumbent regime. The increasing diffusion is accompanied by redefinition of rule sets, and thus also of user needs, resulting in a collective learning processes and eventually, if successful, new stable rule sets.
- Stabilization. As the niche's actors grow in number, and niche technologies mature alongside a stable rules and institutions, the (now former) niche gradually establishes itself as a new regime. Thus, facilitating an increase in adoption as the regime now facilitates and substantiates new behavioral patterns.

Understanding where actors fit within the MLP framework and how they foster transition along these three stages is a growing segment of the transition literature. Under the MLP framework, governance is understood as public decision-making beyond, but also including, the state. While not a rigid characterization, actors who participate in governance are commonly divided into state (government), private sector (business) and civil society actors (Grin et al 2010; Loorbach, 2007) and resigned to specific levels with the MLP, i.e niche, regime, or landscape.

Smith *et al.* (2005) suggests that understanding whether actors are "inside" or "outside" of the incumbent regime is essential in understanding their behavior, and therefore, their options in influencing transitions. The literature also finds that to respond to pressures from niches (bottom-up) or the landscape (top-down), regime actors must find ways to respond to pressure within existing institutions or integrate niche innovations (Smith, 2005). As such, there is a tendency for regime actors to become transition opponents, as "incumbent regime actors initially tend to downplay the need for transformation" (Rock et al., 2009, p. 244). This results in tension between members of the incumbent regime and those striving to create regime change through network or coalition resource flow (Smith, 2005).

One evolving area of the transition literature is understanding the role of intermediary actors, which transcend spatial and societal scales. The characterization of intermediary actors in the MLP framework is analogous to that of Clark's (2017) of third-sector actors. Intermediary actors can include very different types of organizations, such as non-government or semi-government agencies working at different scales (Dewald and Truffer, 2012)

A recent review by Fisher (2016) finds that a number of transition scholars believe intermediaries can play a special role as mediators by providing and distributing necessary information in a transition, ie between the niche and the acceleration phase (Dewald and Truffer, 2012) and between the different applications in creating a vision for niche innovation (Hodson and Marvin, 2007). There is also a great variety in the services intermediaries can provide, such as the provision of energy advice and advice centers; project initiation, management and coordination; consultancy activities; lobbying; education; training and courses; and network building (Hodson and Marvin, 2007). McCauley and Stephens (2012) see the role of intermediaries in the MLP as "connecting niche-level activities with regime level institutions (pg. 213)" as well as diffusing new technology and practices through the regional level (McCauley and Stephens, 2012). Taken together, it is clear that intermediaries serve several roles at every stage of the transition process. What is less clear is the strategies which intermediaries employ to facilitate transition from the start-up phase through the acceleration phase and ultimately to stabilization.

4.3 Third-Sector Intermediaries, Strategic Capacity Seeding, and the City

The role of third-sector intermediaries at the city-level, has historically been characterized as enabling, provisional, and partnership (Fischer and Newgi, 2016). Clark (2017) identifies four types of policy spaces for intermediary actors, including the provision of new services through the diffusion of technology, the provision of old services through new models, the provision of services to new populations, and the establishment of new forms for civic engagement.

In the United States, there are many examples of third-sector intermediaries, increasingly these actors are focusing on energy policy and utilizing the strategy of local level capacity seeding. Examples include the Clinton Foundation, the Rockefeller Foundation, the Bloomberg Foundation, the International Council for Local Environmental Initiatives-Local Governments for Sustainability, the Sierra Club, and the Natural Resource Defense Council. The national intermediaries' presence is often not focused on a single city but rather a network of cities. For example, C40 provides cities with peer-to-peer networks, in addition to providing cities with program design. Localities leverage private foundation funding and these intermediaries' expertise to provide the capacity, direction, and the network to achieve local policy objectives (See Mims et al, 2016). In return, the localities commit to the process and goals established by the intermediary and pursue the suggested program design.

While the practice of strategic capacity seeding is growing among third-sector intermediaries, there is little empirical analysis on the impacts of the approach. In this chapter I focus on understanding the local impacts of this growing trend in intermediary actors of strategic capacity seeding and diffusing specific city-level policies for the support of niche innovation within the electricity system.

4.4 Research Questions and Hypotheses

This research is guided by the presupposition that through systematic and qualitative change in the institutions of cities, sustainable transitions are possible and that the transformations made at the city level will be reflected in any national regime change. Therefore, understanding if and how the strategies of emerging actors are altering the institutions of cities is critical in understanding the contours of national sustainable transitions. With this research, I seek to four questions.

Research Questions:

RQ 1: What motivates localities to pursue third-sector intermediaries and strategic capacity seeding?

RQ 2: Does strategic capacity seeding by third-sector intermediaries change the capacity or the behavior of existing institutions towards further development of niche innovations?

RQ3: Does strategic capacity seeding by third-sector intermediaries improve the role of the public in sustainable transitions?

RQ4: Overarching question: Are third-sector intermediaries just one of many actors within the governance network, or do they, compared to other actors, play a key role in sustainable transitions?

Building from multiple theoretical literatures, I hypothesize that,

H1: Localities are motivated by a lack of capacity and expertise to pursue third-sector intermediaries and strategic capacity seeding.

H2: Strategic capacity seeding will change the capacity and the behavior of existing institutions towards further development of niche innovations

H3: Strategic capacity seeding by third-sector intermediaries will decrease the role of the public in the sustainable transitions.

4.5 Methodology

4.5.1 Approach

To test the above hypotheses, I conduct a case study on the City Energy Project (CEP) in Atlanta, GA. The CEP is an active example of a third-sector intermediary engaging at the city level with the approach of strategy capacity seeding. Specifically, CEP is focused on establish a handful of local policies through the city council that improve the energy efficiency in commercial buildings.

4.5.2 Data Sources

The paper employed primarily qualitative data from both primary and secondary sources. The primary data sources used were in-depth qualitative interviews. I also used a wide range of secondary data sources including: project reports, policy documents, project proposals, and workshop proceedings I studied Atlanta's participation in the City Energy Project for 20 months.

In my research, I conducted several in-depth interviews, attended City Council meetings, reviewed CEP documents, and attended CEP stakeholder workshops. An outline of all the interviews conducted, materials reviewed, and meetings attended is outlined in the Appendix.

4.6 Literature Review

Generally, the term capacity refers to "the ability to perform functions, solve problems and set and achieve objectives" (Fukuda-Parr & al., 2002). The institutional capacity of a local government to achieve a specific energy policy goal refers to the ability of the locality to meet policy goals and objectives. A clear definition of capacity is difficult to find. Chaskin (2001) identified four factors that many definitions hold in common: (1) the existence of resources (from individual skills to access to financial capital); (2) networks of relationships; (3) leadership; and (4) support for collective action and problem solving mechanisms or processes. Capacity building refers to the process of acquiring and managing the resources necessary to achieve policy goals and objectives. Capacity building emphasizes the need to systematically develop political support, financial resources, technologies, and managerial execution in building organizational capacity for policy change (Horton et al. 2003). Recently, capacity has been linked to local governments' involvement in climate-protecting activities (Krause 2011b).

In the United States the movement towards neoliberalism at the national scale in the 70's and 80's led to waves of privatization of public services and the devolution of those services to state, provincial, and local actors (Peck and Theodore, 2015). Local governments, tasked with providing the increasing services but without increasing capacity, responded by contracting services to private market actors (Warner and Gerbasi, 2004). As Clark (2017) notes, on the one hand, "national- scale neo- liberal project championed devolution and deregulation ostensibly to ‘empower’ localities and promote flexible forms of regional governance (p. 814).” In reality, however, the result was not a complete replication of neoliberal reforms at the local level but a subsequent declined in services, resulting in a policy failure and a gap unevenly addressed by private market actors (Ashton et al., 2016). The response was a varied space for institutions to develop innovative models for mediating these gaps, i.e strategic capacity seeding by third-sector intermediaries (Clark, 821).

In concert with the devolution of public services by the State, the history of of U.S. energy policy has developed with an inherent tension over the notion over whether the provision of electricity is a marketable public good or a private good. For example, while wholesale electricity markets are increasingly driven by the rules of competition, recent concerns over the environmental damages of electricity generation and threats to security of supply suggest that citizens are increasingly seeing electricity as a public good.

Sociotechnical landscape pressures such as concerns over climate change and economic development, coupled with the devolution of energy policy in the United States has put pressure on local governments in the United States to implement energy policies with the purpose of improving sustainability (Saha and Paterson 2008). While these landscape pressures may propel a local government to pursue energy policies, institutional capacity will ultimately influence the locality’s ability to pass and implement new policies. The idea of capacity building then assumes that there is a required level of institutional capacity for a locality to carry out its policy goals. Though there are multiple forms of institutional capacity, when examining the impact intermediaries on the capacity of, I am most interested in the dynamics between financial, technical capacity, and political capacity.

Financial capacity is an organization's ability to assemble financial resources to support its operations and missions, most typically with access to human capital. Without the financial capacity to hire staff, manage a policy process, and ultimately implement (then manage) a policy, localities are often reluctant to engage in policy change. The literature shows that localities that have staff dedicated to sustainability issues tend to have broader and more expansive sustainability efforts in place (Homsy and Warner, 2015; Krause, 2012a; Levesque, et al; 2016). While financial resources alone cannot develop a niche innovation, the literature shows that inconsistent financial support and spending reductions can destabilize policy implementation efforts (Vig and Kraft, 2006). As such, it is critical for localities to develop and institutionalize funding mechanisms for local policy goals, particularly in the area of sustainability (Salamon, 2002).

Technical capacity refers to an organization's ability to understand the technical aspects of a specific goal and use the technologies required to achieve the goal. Many sustainability practices involve the understanding of technical concepts or the use of the latest technologies, for example, in areas such as alternative energy, energy efficiency, pollution control and monitoring, and natural resource management. It is necessary to acquire technical savvy and expertise in order to make informed decisions. Developing human capital through internal professionalization as well as establishing complementary ties to external technical resources is fundamental for credibility, for strengthening social norms, and for institutionalizing change (Lubell, Leach, and Sabatier 2009).

Political capacity is the level of support obtained from elected officials, the community, and other stakeholders in implementing supportive policies or practices for sustainable transition.

Support from citizens increases the legitimacy and thus the feasibility of achieving a specific policy goal. Support from elected officials forecloses back channels, legitimates change, and can often help secure financial capacity. Additionally, support from the business and nonprofit community is consistent with the collective action efforts that are germane to building social capital and to comprehensively tackling complex issues such as energy policy through the governance of public and private partnerships (Lubell, Leach, and Sabatier, 2009).

While it is clear that there is a necessity for financial, technical, and political capacity, building these types of capacity is often challenging, particularly in the realm of sustainable transitions. Local sustainability initiatives compete with other spending programs and often lack the immediate benefits those local officials and median voters require for support (Hawkins and Wang 2012; Sharp, Daley, and Lynch 2011), making financial capacity a critical condition for implementing energy policy (Wang et al. 2012). What is still unclear is why some localities commit the financial and human resources and build the institutional capacity for energy, climate, and broader sustainability transitions (Feiock et al., 2014; Portney, 2013). Hawkins (2012) finds that when the citizens consider sustainability a city priority, the city puts greater effort towards the provision of human resources and when cities work closely with other cities or regions, commitment towards human resources tends to increase. However, even when sustainability is a priority, cities can still pursue initiatives in a piecemeal, ad-hoc manner (Saha, 2008).

A recent report conducted by the C40 Cities Climate Leadership Group, *Unlocking Climate Action in Megacities,* found that the key barriers to effective city action on climate change identified in are:

- A lack of co-ordination between city, regional and national governments;
- Green projects falling through the cracks between different arms of city government;
- Collecting, accessing, analyzing and presenting information about the benefits of action on climate change;
- Communicating benefits of green initiatives with citizens and other key stakeholders;
- Failure to work effectively with the private sector; and
- Securing funding for projects in cities.

Additionally, the report found that where cities have the institutional capacity to act, they report taking 30 percent more action than those without, reaffirming they are more likely to implement solutions that will reduce greenhouse gas emissions.

Wang et al (2015) sampled 264 cities and found that 71% of the cities utilized grant applications to finance sustainability initiatives, suggesting a potential limit to local institutional capacity, specifically financial capacity for pursuing sustainability initiatives as well as a threat for continuation of projects that often require consistent funding support. However, Wang et al (2015) also found that community engagement had positive and significant influences on the institutional capacity of cities to maintain sustainability initiatives long-term. If the authority for addressing environmental, economic and social issues is largely held within local governments, and the outcomes associated with different levels of resource commitment have important implications for how localities can advance their agendas, then it is important to also understand how the type of funding may impact the policy process. Additionally, it is important to understand the role of community engagement towards the long-term ‘financing’ of the local energy agenda.

From the literature, it is clear that localities pull from multiple channels to achieve the institutional capacity necessary to pursue its goals, and there is a relationship between a locality’s institutional capacity and their ability to pursue local policy. It is reasonable to assume that many localities desire to implement local energy policies and support niche innovations, but are unable to do so because of resource constraints. From that logic, we see that sustainability and the development of niche innovations tracks in parallel with the greater devolution of public services to localities and the need to outsource capacity. Third-sector intermediaries then provides the localities with capacity-technical, fiscal capacity as well as a social- to provide these services.

H1: City officials are motivated by a lack of capacity and expertise to pursue third-sector intermediaries and strategic capacity seeding.

Large in response to this capacity gap and the opportunity to shape local policy agendas, the third-sector intermediary landscape has developed dramatically in scale and profile. Intermediaries are bigger, more numerous and sophisticated, and have raised more funding than ever before (AbouAssi, 2012, Africa, 2013, Brautigam and Segarra, 2007, Brown et al., 2007b, Clarke, 1998, Fisher, 1997 and Thomas, 2008).

There is great debate within the public administration literature on the benefits and tradeoffs on relying on intermediaries. For the sake of this review, I am focused on third-sector intermediaries, which are typically characterized as NGOs in the administration literature, and their specific goal of filling the gaps in local service. From the literature examining the role of NGO's in providing aide and infrastructure support, there is evidence that while NGO's may do well to serve an immediate need, when the local government is deficient, long-term reliance on NGO's can stunt the local institutional development and inhibit local participation in the governance process (Hulme & Edwards, 1996; Banks & Hulme, 2012).

Inherent in the examination of intermediaries' impact on the policy process is the recognition that there is a difference between short-term and long-term institutional capacity. Kaplan (2000) identified that while governments can obtain short-term capacity infusions- such as increase in monetary incentives or introducing a new information system, without long-term support by a sustained resource and political commitment there will be very little impact on institutional capacity. Kaplan, argues that for intermediaries to be effective facilitators of capacity building they must participate in organizational capacity, including:

- Developing a conceptual framework
- Establishing an organizational attitude
- Developing a vision and strategy
- Developing an organizational structure
- Developing political support
- Developing community support
- Acquiring skills and resources

Kaplan's (2000) distinction between short and long-term capacity and what is needed to build long-term capacity is critical when understanding the goals and strategies of third-sector intermediaries. The function of the strategic capacity seeding, as it is practiced currently, is to provide localities with a limited infusion of institutional capacity, to achieve specific policy goals. This is akin to what Kaplan sees as short-term capacity building. However, it is unclear whether this strategy is capable of building long-term capacity and, more importantly, if the presence of the intermediary may inhibit a locality from building long-term capacity and local institutional development.

Bano, (2008; 2012) found that donor financing actually breaks down the institutions for collective action by eroding the attributes and characteristics that generate membership and support for the organizations. Bano argues that in their quest to strengthen civil society organizations, donors have used incorrect assumptions about why people choose to cooperate in groups, intentions, motivations, and commitments to the cause. There are also arguments against the intermediary's ability to be long-term partners or managers of a local objective, particularly if the local residents' need change and the intermediary is forced to diverge or advance from the initial goal. Andres (2014) found that when tensions arose between the priorities of donors and locals, Intermediaries were forced to drop their support role as a result of donor pressures to keep programs aligned with their priorities. In fact, there is a strong argument that the focus of donors on measurable results has pushed Intermediaries away from developing local capacity (Chang, 2011). Rather, some third-sector intermediaries have been incentivized to pursue their objectives at the expense of their civil society functions. Given their dependence on donor funds increasingly demanding measurable 'results', intermediaries must prioritize their functional accountability to donors (in terms of targets and outputs) over their broader goals of local empowerment to overcome the systems, processes, and institutions that are barriers in the first place (Atack, 1999, Lewis, 2013, Mitlin et al., 2007 and Power et al., 2002).

Such 'professionalization' has led to multiple undesirable consequences, most notably the erosion of participatory approaches, as intermediaries become the implementers of donor policy rather than independent actors (Elbers & Arts, 2011). The great paradox is that the intermediary's capacity to engage in the wicked policy problems and to reach the levels of success desired by donors actually draws them away from establishing the local capacities they need for successful operations on the ground (Balboa, 2014).

However, there are also arguments for the benefits of intermediaries on governance (Boulding, 2010, Fearon et al., 2011 and Moehler, 2010). This stream of literature argues that despite the difficulties Intermediaries face in terms of civil society, they can and do can act as 'schools of democracy' by providing resources and opportunities for collective action, expanding political participation and public awareness, mitigating societal conflicts, and providing channels of interest representation (Boulding, 2010, Fearon et al., 2011, Heinrich, 2001 and Moehler, 2010). The argument here is that Intermediaries have the ability to bring attention to an issue, objective, or failing on the part of the local government. And by doing so the intermediary creates a channel for participation and ultimately local capacity building (Heinrich, 2001, Mercer, 2002 and Thomas, 2008). Recent studies have provided evidence that intermediaries can promote democracy through increasing community-level interactions, and promoting social capital (Boulding and Gibson, 2009).

Still, the theoretical and empirical research suggests that a critical element for successful plan development and project implementation is the collaboration and participation by the local community and stakeholders in the policy process (Brody, 2003a; Portney, 2005, 2009). This is especially true for local efforts. As Portney and Berry recognize, “unlike national politics, with its reliance on representative government, urban policy making can offer opportunities for direct citizen involvement and even face-to-face democracy at the neighborhood.” The presumption is that broader levels of community participation will be linked to greater responsiveness by city governments. And for decades the literature has recognized this idea that without real “buy in” from citizens, any broad initiative faces a perilous route to enactment (Brugman, 1997; Portney and Berry, 2010). If a locality is to develop and implement a climate change, energy management, or broader sustainability initiative, the confidence and cooperation of its residents is critical (Brugman, 1997). As Zachary (1995, 30) states, “community involvement can be a key factor in developing tools for moving toward a more sustainable community.”

There are several rationales for why public participation is necessary, ranging from the observation that establishing significant participatory deliberative democracy platforms (through which residents can achieve some degree of consensus on the idea that sustainability) is a desirable community good will insure that sustainability becomes a staple of the community and not a policy agenda of the few (Baber and Bartlett 2005; Miller and Buys 2008), to the idea that when cities participate in the public policy-making process, widespread public support could provide countervailing power against business interests antagonistic to particular proposals (O’Connell 2009). Kobler (2009) found Seattle’s decision to build local community support for its sustainability efforts ultimately provided the city government with greater capacity to achieve sustainability goals.

Of course, there are also debates over the effectiveness of wide-spread public engagement in sustainability pursuits, including the potential for strong opposition against sustainability (Groc, 2007). Berry (1999) recognized that often, public participation on sustainability efforts are correlated with elite social groups. But as Portney and Berry (2010) point out, effective public engagement may actually succeed in broadening participation beyond the "usual suspects."

Under a strategic capacity seeding model, the locality locality achieves instant access to capacity support, from the third-sector intermediary to achieve a policy goal. While the NGO literature is mixed on the implications of utilizing third-sector actors towards achieving local policy objectives, the historical and political context at play will shape every outcome and the mechanisms through which policies are promoted and achieved. But the literature does suggest that the presence of a national or international third-sector actor in local policy making could have both positive and negative effects on local institutions. On the one hand, intermediaries can bring attention to local policy concerns and provide the support necessary to create the institutional capacity necessary for policy change. On the other hand, intermediaries could sideline the political capacity necessary to establish the institutions and long-term institutional capacity necessary for true sustainable transitions. The inclusion of the public and community support is critical to building long-term institutional capacity for local policy efforts and the presence of a third-sector actors with a focus on immediate results and not long-term institutions may undermine the role of the public.

H2: Strategic capacity seeding will change the capacity and the behavior of existing institutions towards further development of niche innovations

H3: Strategic capacity seeding by third-sector intermediaries will decrease the role of the public in the sustainable transitions.

4.7 Case Study on Atlanta and the City Energy Project

The City Energy Project (CEP) is a national initiative supported by the Natural Resource Defense Council (NRDC) and the Institute Market for Transformation (IMT) and funded by Bloomberg Philanthropies, The Kresge Foundation, and the Doris Duke Charitable Foundation. The purpose of the CEP is to improve the energy efficiency of existing buildings in major American cities. The CEP is an active example of a third-sector intermediary engaging in strategic capacity seeding in networked localities with the goal of producing national transition in the energy system, specifically energy efficient buildings.

In the first round of CEP, ten cities were chosen to participate in a network of cities that would work to improve energy efficiency in buildings. These cities were: Boston, Philadelphia, Atlanta, Orlando, Chicago, Kansas City, Houston, Denver, Salt Lake City and Los Angeles. The CEP provides each participating city with funds to hire a full-time advisor for three years. The CEP advisor is responsible for passing and implementing a customized energy efficiency goal of reducing energy use in buildings. CEP also provides funds to local partners to support the localities' pursuits. To achieve the goals of CEP, NRDC and IMT (hub staff) have a set of energy efficiency policies that each city pulls from and tailors to its local market. The primary policies that the CEP focuses on are energy benchmarking and disclosure (also called reporting or transparency). CEP hub staff also work to maintain a network between the participating cities and facilitates interaction between cities to share best practices and experiences.

Cities are chosen based on a number of factors, including the political feasibility of passing the CEP policies. However, cities acceptance into CEP is not contingent on the localities' historical energy policy. Rather there are some cities with relatively strong energy policy portfolios going into their participation in CEP while others have very few policies on the books. Additionally, the institutions of each participating locality are very different. Some cities have multiple people working in their respective energy or sustainability departments while some cities have only one or two people on staff; some cities have very energy-oriented city agendas while others do not; and some cities have very supportive local and state legislation, while other cities have strong political opposition. Largely the consistency between the cities is in the barriers to passing energy policies targeted at commercial building management. All cities have faced similar opposition from a single, national trade group- Building Owners Management Association (BOMA)- as well as a variant opposition from city legislatures, state legislatures, and local trade groups. From a sociotechnical perspective, these actors represent regime actors that are resistant to the niche innovation of energy efficient buildings or the governments mandate of energy efficient buildings. By creating a mix of cities, facing different challenges, there is room for both shared learning between the cities and between the hub CEP staff and the city representatives.

While each city CEP representative is funded by the CEP project, it is up to the participating City whether the representative is treated as a city employee or as an outside consultant. The representative is funded for three years, at which the locality must choose to either support the ongoing position or end the employment.

City representatives have a limited timeline and funding to accomplish the CEP goals of passing local energy efficiency policies. However, the hub staff understands that many of the participating cities will not pass energy policies within the timeframe. As Kimi Nartia, the Deputy Director for CEP stated, “we all understand the politics of policy and that some cities will take longer than three years, but our goal is to have those cities set up for success.” Additionally, CEP cities continue to have access to the hub staff resources and advice even after the three-year timeline is over.

Atlanta is the capital of and the most populous city in the state of Georgia, with an estimated 2015 population of 463,878. Atlanta’s metropolitan area is home to 5,522,942 people and is the ninth largest metropolitan area in the United States. Atlanta is traditionally a strong-mayor-council with considerable power resting in the hands of the mayor.

As part of its CEP participation, Atlanta chose to pursue three energy efficiency policies: *Benchmarking, Reporting, and Audits*. Atlanta passed its ordinance in May of 2015. Atlanta was the first of the CEP cities to pass its proposed legislation. Table 5 provides the specifics of the ordinance pursued by the City.

Table 4-1 City Energy Ordinance Specifics

Ordinance	Specifics
Benchmarking	Atlanta's ordinance states that benchmarking (as well as reporting) of energy and water data be phased in by building ownership, type, & size, as follows: <u>City Buildings >10,000 sqft, Non-City Buildings >50,000 sq. ft.</u> ▪ Buildings are currently reporting previous-year data <u>Buildings >25,000 sq. ft.</u> ▪ By June of 2017, previous-year data must be reported
Reporting	Requires building owners to submit a benchmarking summary of their covered properties to the City system using Energy Star Portfolio Manager.
Audits	Atlanta's ordinance requires covered properties to undergo audits every ten years. While audits identify cost-effective measures, the proposal does not mandate that any of the measures are implemented

The potential benefits from passing these three policies are substantial. Recent research on Atlanta's ordinance found that the combination of benchmarking, reporting, and audits could result in an energy savings of 858,248 MWh through 2020, growing to 1.7 billion MWh by 2030. Cumulatively, the proposed policies could result in $291 million in energy bill savings through 2020, growing to $1.9 billion in 2030, with annual job growth ranging from 1,470 to 1,870 jobs per year. Finally, Atlanta's ordinance could result in 139 billion gallons of water saved, while CO_2 savings could exceed 5 million metric tons, or about 29% of commercial sector emissions in 2013 (Cox and Golin, 2015). Needless to say, the passing of these three policies would mark a substantial movement towards the transition of energy efficient buildings

4.7.1 Motivation for Atlanta's participation in the City Energy Project

Atlanta had multiple motivations for participating in CEP. The first was attaining the institutional capacity necessary to achieve previously established policy goals. Prior to pursuing the CEP, Atlanta had independently engaged in a Power to Change sustainability plan. The Power to Change process included several hundred stakeholders to determine which areas of Atlanta the Mayor's Office should target for improvement. The result of the stakeholder engagement was a commitment to reduce energy and water consumption in the City. When the City was contacted about the CEP, participation provided a pathway to pursue their previous motivations.

More importantly, when Atlanta first considered becoming part of CEP, the sustainability office, which is the office that would ultimately apply for CEP participation, was not on the City's general fund. The funding that Atlanta would receive from CEP was more than half the total annual budget for the City's Sustainability department, at the time. Denise Quarles was the Director of Sustainability when the Office of Sustainability decided to pursue CEP. Quarles stated, "CEP provided [the City] with the money and the knowhow to reduce our energy use… it also guided us through the process. I was familiar with benchmarking and retrofitting, but I knew that we had made it a goal to reduce our energy use."

Additionally, the Mayor was interested in becoming part of an exclusive premier set of 10 cities participating in a national initiative. Participation in CEP would give Atlanta high visibility on the national stage for energy initiatives. However, despite the motivations to be recognized in a select group, there was very little public promotion of Atlanta's pursuit and ultimately acceptance in to the CEP. Matt Cox was hired as Atlanta's CEP representative. Cox stated, "Participation in CEP was politically contentious and not anything that the City wanted to promote politically. In large part, this was because CEP necessitated pursuing legislation that would undoubtedly receive resistance from a portion of the building owner and development community- which is a very strong economic driver in Atlanta. Instead, the City promoted initiatives such as volunteer programs, like the Better Buildings Challenge, and the City's push to put solar on municipal buildings…. in terms of total energy savings, these smaller initiatives have a minimal impact compared to the potential energy savings from passing the CEP ordinances. But the volunteer programs were discussed much more publically because it was more well received from a political standpoint."

In contrast, on the National stage, Atlanta consistently promoted its participation in CEP. Once part of CEP, Atlanta was the first city to pass its ordinance. In doing so, it became the first city in the south to pass such legislation, raising the city's profile. The increased recognition was made evident by the fact that the Mayor was asked to speak at higher profile, energy-related, events, including the Climate Talks in Paris. Despite downplaying the notorious local press, the City encouraged recognition on the national stage.

Finally, the ability to learn from other cities was a major motivator for participating in CEP. Quarles stated, "Our office was small and we needed to lean on other offices to really understand not only what we wanted to do but the impacts of what we were doing. Getting to see how different policies played out in other cities was very helpful." Referring to our framework, the 'other cities' referred to by Quarles, is comprised of the city network that was managed collectively by the centralized NGO, CEP. Quarles, who as Sustainability Director, was also part of other city networks, found that the city network platform established by CEP provided an additional benefit because the conversations and idea sharing was narrowed to the passage of a specific policy or type of policy. In other networks, such as the Urban Sustainability Directors Network, there is a broad arrange of conversation that may or may not be relevant.

Atlanta's motivations were similar to other CEP participating cities. Kimi Narita is the Deputy Director for City Energy Project and works for NRDC. Narita works closely with every city participating in CEP and directs the political strategy that every city takes when pursuing local policies. Narita stated, "[cities] just need a jump start to pursue these policies… cities don't know how or if they can reduce their energy use and they don't have the money to figure it out, [CEP] is the jump start."

Consistent with the policy literature, Atlanta had limited financial and technical capacity to pursue local energy policies, particularly ones that would regulate the actions of a specific group of people. CEP provided the financial and technical capacity needed. When Quarles and Cox were asked if Atlanta would have pursued the policies of benchmarking, transparency, or audits irrespective of participation in CEP, both said no. Cox stated, "I presented my research to the City years before CEP and told them they should pursue these policies, but there wasn't the ability or understanding. Maybe eventually Atlanta would have done this but I highly doubt it."

In terms of political capacity, Atlanta had the full support of Mayor Kasim Reed before deciding to participate in CEP. Cox stated, “If Kasim Reed hadn’t supported participation we would have never engaged.” However, there was not wide-spread support throughout Atlanta. In large part, the reason why Atlanta would not have been able to pass and implement the CEP policies was directly related to the amount of resistance the City expected to receive from regime actors, specifically the building-owner community. As Quarles stated, “its takes a lot of time and effort and intelligence to pass these types of policies when there is a large, connected, and wealthy group of people who don’t want be told they have to do something.” However, the strong opposition that was posed by the building-owner community was not the only stakeholder considered before Atlanta decided to participate in CEP. There were several local niche actors (users and intermediaries) that supported Atlanta’s pursuit. Before agreeing to participate in CEP, Quarles outlined the local actors that would be eventual allies in any political struggle.

The stakeholder with the greatest support for Atlanta’s participation in CEP was Southface Energy Institute. Southface, once a volunteer organization, is an Atlanta-based NGO that focuses on sustainable development through education, research, advocacy and technical assistance. Southface received funding from CEP to support Atlanta in its efforts. Robert Reed is the Director of Sustainable Communities for Southface and was the primary person at Southface who worked with the City to pass the ordinance. Once the ordinance was passed, Juliette Apicella, the Program Manager for the Atlanta Better Buildings Challenge, was very involved with developing the implementation plan. Southface’s primary role in assisting Atlanta was to help provide stakeholder support for the ordinance. This involved organizing supporters of the ordinance to testify in front of City Counsel in support of the ordinance and provide policy advice to Atlanta during the process. From a sociotechnical perspective, Southface exists as a niche intermediary, as one of the local stakeholders that help support and facilitate sustainability and energy policy goals, but not one that engages in strategic capacity seeding.

What Quarles did not do, nor did Cox, was examine what role the general public would play in pursuing the CEP policies. Receiving the financial capacity that would have provided Atlanta with a platform for engaging the public was not a motivator for participating in CEP. As explored later, this was not a priority either for the City or CEP. The focus really remained on combating opposition and organizing stakeholder support.

Participation in CEP provided Atlanta with the financial and technical resources necessary to implement policies that may have otherwise been too politically difficult to achieve. However, it is important to recognize that the political opposition was not from the Mayor but from the local building community that would ultimately be subject to the new regulations. Atlanta generally had the political capital, related to elected officials, that it needed to pass the CEP policies due to Mayor Kasim Reed's strong support. The City was aware but unsure about the strength of the political opposition of building-owner community before participating in CEP. Regarding CEP, the City was not focused on the opinion of the general public. Acceptance into CEP meant that Atlanta would have the financial, technical and at least portions of the political capacity necessary to achieve energy policy objectives.

4.7.2 Influence of a Strategic Capacity Seeding on Institutional Capacity

Once accepted into the CEP, Atlanta was given a budget by CEP to hire staff for the CEP as well as a budget for engagement. Additionally, CEP provided funds for an independent consultant to work with the City and funds to a local partner organization - Southface Energy Institute- to support the process. Atlanta hired Matt Cox, a recent graduate of Georgia Tech with a PhD in public policy to manage all of its CEP efforts. Despite a deep understanding of energy efficiency, Cox did not receive any training from the City or CEP staff. Before Cox was hired, Quarles had already decided on which policies the City would pursue - benchmarking, and transparency. The original plan for Atlanta did not include audits or retrocommissioning, but was added later on the guidance of Cox. While CEP staff provided guidance, the City was responsible for creating their own internal documents to determine what and how the City would pursue certain policies, and how the City would measure progress. However, every City participating in CEP was strongly encouraged to pursue the core policies of benchmarking and transparency of commercial buildings. Upon arrival, Cox was handed a folder of documents that detailed the policies the Office of Sustainability wanted to pursue, the timeline of pursuit, and the resources available. The CEP staff, based on the documents compiled by Quarles, would review Atlanta monthly. It should be noted though that no city entered into a binding contract with CEP that exchanged funds for passing a certain law.

Once hired, Cox was immediately placed into the network of ten cities' representatives as well as the CEP Hub Staff - comprised of NRDC and IMT staff. Atlanta had scheduled weekly engagement to review strategy and approach with the CEP staff. The CEP staff largely divided in to topic areas, with NRDC taking the political lead and IMT advising on technical questions. Every two weeks, all ten cities were required to participate in a webinar or conference call, with the goal of learning from each other on how to handle political obstacles. However, despite the scheduled interaction, according to Cox most exchanges with hub staff were unplanned and focused on political guidance.

Compared to other cities, Atlanta received substantial technical understanding as a result of hiring Cox. Where Atlanta needed guidance from hub staff was in political strategy. Atlanta, experienced substantial pushback from three primary groups - the Building Owners and Managers Association (BOMA), Commercial Board of Realtors (CBR), and the Atlanta Apartment Association (AAA). There was also some resistance from the Georgia Hotels and Lodging Association. BOMA, an international organization, actually fought against all of the CEP cities attempt to pass the energy efficiency ordinances. Despite each city having similar oppositions, Atlanta did not go to the other cities for political guidance, but turned to CEP staff. From Atlanta's perspective, the CEP staff was more knowledgeable about political strategy then other cities. During the process of designing and passing ordinance - at least daily, often multiple times a day - Cox was in conversation with CEP staff. Hub staff also provided guidance on other concerns such as assistance on how to best design a flyer or how to best communicate a message, and more importantly how to write the ordinance. CEP staff was specific on the type of language that the cities needed to use in their engagements.

There were several times throughout the process, where CEP hub staff became critical to Atlanta's pursuits. Relative to other cities, Atlanta moved very quickly in the process. Cox independently conducted an impact study on the benefits of the ordinance- in terms of energy saving, energy expenditures, health saving, carbon savings, and job growth potential. In the first meeting with Mayor Kasim Reed, presenting the ordinance and the impact study, Cox said that the Mayor read the study and said "give me a bill to sign within two months." The Office of

Sustainability, Cox, Quarles, the local partners, or CEP Hub Staff, did not expect this type of aggressiveness. Given that Atlanta's Mayor was eager to pass the CEP ordinance, Atlanta's timeline was accelerated and in fact, CEP staff had not written a draft template ordinance prior to Atlanta beginning the legislation process. As a result, Atlanta (unlike other CEP cities) was in constant conversation with CEP staff, specifically related to language of the ordinance, how to engage adversarial parties, and how to develop a context so that Atlanta could garner national, state, local support for its efforts. Due to the compressed timeline, CEP hub staff became critical in assisting with political strategy, crafting a successful letter of support, developing public-facing information on the ordinance, and acquiring key political support from specific organizations or people.

A prime example of CEP hub staffs' importance actually occurred after the ordinance passed. Six months after the City passed its final CEP legislation, there was an attempt to undermine the ordinance at the State level. Backed by the Council for Quality Growth, legislation was introduced to ban the City from passing any mandated transparency laws related to energy consumption. The CEP hub staff became extremely involved in coordinating local players to help stay the bill, going as far to hire a local lobbyist. Ultimately the state legislation never made it out of committee and the CEP ordinance was upheld. These two examples highlight how the third-sector intermediary utilizes the strategy of capacity seeding to strategically interact directly in the policy process, and difference with other observed third-sector relationships. As opposed to other arrangements where the locality may receive funding or just technical support from a third-sector actor, under a strategic capacity seeding model the third-sector actor becomes an active player in defining, crafting, and implementing the local policies and engaging in any local political barriers.

However, for as much effort as the CEP hub staff put towards the political preservation of the ordinance, the greatest political capital came from the Mayor. In both the passing of the ordinance and its later defense, the Mayor took a strong stance in support. The Mayor's support was invaluable in both. So, while the CEP hub staff provided the resources and the ground game for passing and defending the CEP policies, ultimately it was still the Mayor whose influence was greatest. Had CEP not had the Mayor's unwavering support, it is unlikely the City would have ever pursued legislation, passed legislation, or defended it post. From a sociotechnical perspective, we see that while the third-sector intermediary is extremely influential, it is balanced with the existing political structure and must work in concert with the local authorities.

4.7.3 CEP Influence on Institutional Capacity and Local Institutions

As outlined previously, the involvement of third-sector intermediaries in the local policy process can impact the local institutions, both positively and negatively. Participation in CEP meant that Atlanta received technical support, funds for the employment of a CEP manager as well as funds to help support local coalition building, awareness, and education. However, by receiving the CEP funds, Atlanta committed to the CEP approach to the policy process, which did not include a strategy for public engagement, outside of a limited stakeholder group. In this section I examine how Atlanta's participation in CEP impacted the City's institutional capacity for enacting policy change. Additionally, I examine whether participation in CEP limited the role of public participation in the policy process.

Participating in CEP provided Atlanta with immediate access to technical resources, funding for a fulltime employee, funding for an outside consultant, funding for the local partner organization, and funding for general outreach and education. As noted, the amount of funding that the Office of Sustainability received for CEP was roughly one-third of the entire Department's annual budget. Access to resources that otherwise would have been fiscally prohibitive meant the City could take on initiatives that would be politically prohibitive.

However, it is important to recognize that the expansion of institutional capacity does not guarantee a policy change. Despite the expanded capacity to pursue its policy goals, ultimately the City's passing of the ordinance hinged on the Mayor's support. Many other cities engaged in CEP were not able to achieve any policies related to energy efficiency. As Cox stated, "The ordinance wouldn't have passed with the Mayor using his political capital to push it through and honestly Atlanta would have never even applied for the CEP without having his support in the first place."

Shortly after the ordinance passed, Cox resigned as CEP representative and was replaced by Megan O'Neil. O'Neil's primary role was to manage the implementation of the ordinance and to develop a water audit standard that would support the water audit component of the ordinance. While Megan was initially hired on using CEP funds, she has recently accepted a position at the City using the City's general fund, not with grant money. O'Neil's position remains to maintain the implementation of the ordinance and work on any additional energy policy efforts related to energy efficiency. Undoubtedly this position would have never existed had Atlanta not participated in CEP. O'Neil also serves as a bridge between Atlanta and other CEP cities, and maintaining that network is one resource that is valuable to Atlanta. O'Neil stated, "I'm in fairly constant connection with the other CEP cities and Hub staff and I think that will remain even after Atlanta's participation in CEP is over."

However, after the CEP ordinance passed, the number of people dedicated to energy related policy efforts actually reduced. When Atlanta first received the CEP funds there were seven people at the City working on energy related matters. Within three months after the ordinance passed, there were only two people working at the City dedicated to energy policy efforts, reducing the human and technical capacity to work on energy efforts. In large part, the retraction in focus on developing the specific niche innovation of energy efficient buildings was a result of the change in leadership at the Sustainability Department.

Immediately after the ordinance passed, the Sustainability Office received a new director, Stephanie Stucky Benfield, whose focus was not on energy efficiency. As a result, the institutional capacity dedicated to energy efficiency, and energy policy more broadly, was reduced. Here again we see that the existing leadership remaining the dominant influence. While CEP provided an infusion of short-term institutional capacity to achieve a policy goal, once that goal was achieved, the institutional capacity dedicated towards energy policy reverted to pre-CEP levels or less. However, both Cox and O'Neil confirmed that the retraction does not imply that the City wouldn't dedicate more time and resources in the future to local energy policy efforts. Cox stated, "the Office is focused on getting grants. If a grant came along that was focused on [energy policy] then they would pursue it. But right now, they are not going to independently pursue any [energy policy] efforts." Meaning that despite the infusion of capacity to achieve energy efficiency policies, the City was not motivated to independently pursue developing that niche without third-sector intermediaries.

Despite a change in leadership, participation in CEP did result in the creation of a few new institutions that could be beneficial in the sustainable transition. The two major institutions that developed as a result of Atlanta's involvement in CEP, and the passing of the ordinance, are a standardized water audit for the City and Property Assessed Clean Energy (PACE) financing. The ordinance required commercial buildings to conduct a water audit. However, when the ordinance passed there was no national, commercial water audit standard. As a result, Atlanta began developing the first commercial water audit standard. This meant that the Sustainability Department would need to work with the Department of Watershed Management, locally, as well as with other national experts in the field. This created a closer relationship between the two departments, as well as more engagement from the Department of Watershed in energy related matters. Additionally, in pursuit of creating a water audit, Atlanta reached out to experts all over the country. O'Neil stated, "creating the water audit was something [the Office of Sustainability] had to do from scratch. We held working groups, flew in experts, researched other cities and learned a lot in the process." The water audit was finalized in November of 2016 and marks the first of its kind.

In addition to the creation of a standard water audit, participation in CEP assisted in Atlanta's passing of PACE financing. PACE financing was a policy that Atlanta was pursuing before participation in CEP. Before passing the ordinance, the City encountered substantial objection over the potential cost of retro commissioning, a component of the original ordinance that was ultimately dropped due to pushback. PACE financing would have allowed building owners to perform retrocommissioning through PACE finance rather than direct capital. Both Cox and O'Neil felt that retrocomissioning might have stayed as part of the ordinance had PACE been available. Following the passage on the CEP ordinance, O'Neil and Benfieled worked to get PACE passed in Atlanta.

CEP's impact on the City's institutional capacity and institutions for energy policy have been mixed. Certainly, participation in CEP resulted in short-term capacity increases. Participation in CEP meant a short-term infusion of financial and technical resources, with the purpose of pursuing specific policies outlined by the CEP. In terms of long-term institutional capacity, the impacts are less clear. On the one hand, participation in CEP resulted in the full-time employment of Megan O'Neil and the ongoing efforts to manage the ordinance. O'Neil maintains the network established with participation in CEP- with other cities and with hub staff- and intends to even after CEP funding runs out. However, once the ordinance was passed the efforts towards local energy policy contracted. As Cox stated, "It wasn't a situation where [Atlanta] participated in CEP and then the Sustainability Office decided to keep pushing for more energy management or local policies. We passed the ordinance… the leadership changed, and energy efficiency wasn't the focus anymore." Despite the contraction in dedicated institutional capacity, participation in CEP did result in the creation or establishment of two institutions that will undoubtedly support the City in any future policy efforts- a standardized water audit and PACE financing.

4.7.4 The Role of Public Participation in CEP

The literature has repeatedly recognized the importance of public participation and building community engagement in the local policy process. As participants in CEP, and throughout the policy process, Atlanta's approach to public engagement was primarily focused on special interest and mitigating opposition. Cox and Quarles conducted over 150 meetings with relevant stakeholders, including the primary opponents to the ordinance and the key business or institutions that would lend support for the ordinance. However, there were no attempts made by the City to gain widespread community support or educate the general public on the purpose or the potential for the ordinance or the benefits of energy efficiency more broadly. As Cox stated, “CEP, in general, is more focused on overcoming any opposition then it is on building extensive public support.” While hub staff did not prevent Atlanta from engaging with the public, there was no CEP plan for public engagement nor was Atlanta encouraged by CEP to build local support. Rather the focus was on ensuring political support through relevant stakeholders to overcome any political opposition. Cox stated, “hub staff would say that you have to have public engagement, and meetings with the right people. However, that does not amount to widespread public engagement. And in all fairness, Atlanta generally don’t pursue that general public approach.”

To that end, hub staff was extremely influential in guiding Cox, Quarles, and later O’Neil in pursuing what hub staff felt, at the time, to be the most effective strategies for engaging with opponents to the ordinance. As noted, Atlanta’s pursuit of the ordinance was not without opposition. The vast majority of Quarles and Cox’s public engagement was focused on assuaging the regime opposition to BOMA, CBR, and AAA. This meant negotiating on several aspects of the original ordinance and ultimately the removal of retrocommissioning. At one point in the process, Quarles and Cox posted the ordinance on the City’s website with all of the comments made by the opposing parties and all of the concessions made by the City, in an effort to publicly showcase both how accommodating the City had been and how difficult the opposition had been. While ultimately all political strategies and decisions were made by the City, given that Atlanta was the first CEP to pass an ordinance, and both Quarles and Cox had limited experience, everyone involved in Atlanta was, as O'Neil stated, "just figuring it out."

The limited timeframe that cities have to pursue CEP policies presents a barrier to widespread massive engagement. But it is unclear whether Atlanta would have pursued greater community involvement if the Cox states, "In three years, there really is only so much a City can do…the City had developed the Sustainability Plan with public participation, so our job was to take those goals and turn them in to policy. Did we pass an ordinance that we knew the general public wanted? We couldn't say that. What we can say is that the general public wanted cleaner energy- CEP checks that box."

When asked whether not including the public in the policy process was a mistake, O'Neil, Reed, Quarles, and Cox gave mixed responses. Quarles largely did not expect the type of opposition the City received and really felt there was not enough time to engage the public and manage the opposition. Reed would have liked to engage more of the public but that was not the focus of his position. Cox an O'Neil both felt that the public should have been included. Cox stated, "I think if we would have gained public support we could have kept retrocommissioning and we would have had a stronger ordinance." O'Neil also thought that not including community building in the policy process and not engaging the public in the crafting and support for the ordinance was an oversight made by the CEP staff. O'Neil stated, "No one really knew what to do, and neither [Quarles] nor [Cox] had any experience with this type of process, so [Atlanta] looked to hub staff, but even this was new for them, Atlanta was the first City to do this under CEP. "O'Neil also noted that the omission of building institutional capacity in the form of community support was something CEP has recognized. O'Neil stated, "[Hub staff] weren't always correct. And I actually think they learned from it. I think CEP realized they needed to have the public support. In fact, L.A just hired a community engagement person to help with their efforts."

Atlanta's participation in CEP did not focus on building local community support for the ordinance specifically, or energy policy more broadly. However, it is unclear whether building that type of institutional capacity would have directly impacted the ordinance passed under CEP or if CEP had not been involved if the public would have been engaged much past the initial stakeholder meetings. It is possible that even with broad public support, the ordinance would have passed in the same timeframe with the same components.

What is clear, however, is that the focus of CEP hub staff was not on qualitatively changing the behaviors or values of city residents, or developing the community support for niche innovations. Furthermore, the financial and technical support provided by CEP was narrowly focused on achieving a specific policy objective and not focused on changing the subsystems that guide electricity use. Similarly, the policy advice and political capacity provided by CEP was also focused on short-term opposition and not on building long-term institutional support for energy efficiency. However, none of the parties interviewed felt that CEP had undermined the inclusion of the public in the policy process in Atlanta, rather it was a missed opportunity that hopefully CEP participants in the future would learn from.

4.8 Discussion

There are clear benefits of the third-sector intermediary, strategic capacity seeding model. In the case of Atlanta's participation in CEP, passing the recommended energy efficiency policies of the will result in substantial gains towards sustainable transition goals and develop the niche of energy efficiency by broadening the user base throughout the City. Atlanta's participation in CEP provides the financial and technical capacity necessary to niche development in a way that may have otherwise been out of reach for the locality and also resulted in the creation of new institutions and efforts which may in time prove fruitful for the sustainable transition. However, there are tradeoffs. As part of the CEP, Atlanta relied on CEP to finance and direct the cities' pursuits. Additionally, at no point did Atlanta or CEP hub staff engage the general public in the policy process or work to build long-term institutional capacity to support future energy policy initiatives.

Atlanta's participation in the CEP is only one example of a locality utilizing a the third-sector intermediary and the strategic capacity seeding model to develop a niche innovation. While Atlanta's experience cannot define the future of this approach or dictate how cities collectively adopting this model will contribute to a national transition, it does identify a number of the dynamics that should be considered when looking at localities as 'test-beds' for national transitions. Specifically, that the consequences of third-sector intermediaries' involvement in the policy process as well as locality's consistent reliance on external funding to achieve policy goals. My research was driven by recognition that in some cases there is an inherent tradeoff that exists in new governance arrangements between acquiring the capacity to achieve energy policy goals with equity in the policy process and the sustainability of the approach for policy making. By reducing the participatory element of energy policy making, localities may indirectly reinforce the need to rely on third-sector actors to support its efforts.

The literature is consistent that localities are often strapped for resources and a major motivation for engaging Intermediaries is the need for additional capacity. Our research presented here supports the idea that Atlanta was both motivated by a resource need and that CEP did provide the capacity necessary to pass a local energy policy agenda. In Atlanta's case, the building ordinance was passed quickly and the City was able to avoid the regime pushback from the State. All of the staff members agreed that without involvement of CEP, the building ordinance would not have even been pursued, let alone passed. It is clear that the strategic capacity seeding arrangement provided Atlanta with the capacity it needed to pursue its local energy policy goal. However, in Atlanta's case, the increased capacity did not include strengthening public participation.

From the transition literature, we see that the involvement of the public and users is beneficial, and potentially critical, to the longevity of local policy initiatives. As Schot et al (206) recognizes, achieving a transition towards an energy-efficient system, goes beyond individual consumer choice and puts shared routines at the center of system change. To accomplish a sustainable transition, users who are important stakeholders in the innovation process and shape the new routines of system change must be at the center of building the sustainable institutions.

What could be a potential danger of the strategic capacity seeding arrangement, in this case and in other similar programmatic and policy network designs, is the potential to subvert the public interest and engage the user in the sustainable transition. The concern around the public interest arises in that while Atlanta made no effort under CEP to engage the public, it is not necessarily the case that it would do so outside of CEP, and with certain policy preferences from the third-sector intermediary, may not even be preferable. Many policies become law and retain their form despite public values being aligned against them; such governance structures would not be immune from mobilizing a set of cities to pursue policy goals that were opposed by the local citizenry without establishing specific checks and balances. Such checks and balances do not appear present in existing capacity seeding strategies; practitioners need to focus on creating such guiderails and evaluation metrics to ensure that the public interest is protected and promoted instead of ignored or even harmed by these governing frameworks. With the addition of those guides, third-sector intermediaries can leverage the power of cities to institute sustainable change and protect against anti-democratic abuses of power simultaneously.

Whether or not strategic capacity seeding by third-sector intermediaries becomes the ‘norm’ for localities to develop niche innovations and pursue sustainable transitions in the energy systems will likely rest in how localities’ respond to the “jump start” provided by the intermediary and the expectations of the intermediary. If CEP, and similar structures, serve only to provide the upfront resources necessary to educate and motivate cities to commit the internal resources necessary to change or develop institutions towards a sustainable transition, then it is possible that the seeding strategy could include the elements of public participation and local community capacity building that the sustainability literature has recognized as so critical. If, however, localities come to rely on third-sectors to finance its energy efforts, intermediaries continue to focus on short-term policy wins over long-term capacity building, and city employees are left to essentially fundraise for their purpose in the City, it is reasonable to assume that the policy process will be held accountable not to local constituents but to the third-sector actors whose resources are being leveraged. This does not, of course, mean that the intermediaries, such as NRDC and IMT, do not value local input, but rather that in the complexity that is energy policy, creating a platform for local voices may not be a top priority. At the individual, local level, this strategy may result in 'fast policy' wins (Peck and Theodore, 2015) but as a national strategy for sustainable transitions, the idea of undermining or ignoring the role of the public and users may be a non-starter. As the literature repeatedly recognizes, without public support and long-term institutional capacity, the process for achieving sustainable transition can remain perpetually at the niche level.

4.9 Conclusions

Over the past decade, there has been a substantial growth in the role of third-sector intermediaries paired and the use of strategic capacity seeding to facilitate sustainability transitions and achieve specific energy policy agendas. However, there is little research exploring the dynamics and implications of these arrangements. In this research, I use the MLP framework to organize the role of third-party intermediaries in sustainable transitions and build on the work by Clark (2017) to examine how the strategy of strategic capacity seeding is influencing the governance process towards sustainable transitions in cities. I then explore the dynamics and implications of the third-sector intermediary, strategic capacity seeding strategy on the local institutions and institutional capacity of cities.

This research examined Atlanta's participation in the City Energy Project as a means to understanding the motivations behind the use third-sector intermediary, strategic capacity seeding, the impacts of capacity seeding on short and long-term institutional capacity as well as local institutions, and the role of public participation in a third-sector intermediary led approach. Atlanta's experience in CEP highlights the benefits of strategic capacity seeding. Localities are often under resourced and unequipped to engage in local policies, particularly those that require regulations. The results of my research suggest strong support for my first hypotheses, and mixed support for my second two hypotheses. In answering my first question, I find strong support for our hypothesis that localities are motivated by a lack of capacity to achieve local energy policy objectives. This is consistent with the literature. I find mixed support for my second hypothesis that engagement with third-sector intermediaries will result in a gain to the localities' capacity to achieve local policy goals, at least in the short-run. This suggests that the arrangement can be an effective tool at achieving explicit and targeted policy goals, which also may be an improvement upon other governance designs, like city networks, which have received mixed results in the literature. Atlanta's participation in the CEP did result in some long-term institutional gain, as shown by the establishment of the Water Audit and the full-time employment of Megan O'Neil as a city employee. However, the City also witnessed a contraction in efforts dedicated to energy policy after the Energy Efficiency Ordinance passed. This may suggest that the capacity seeding strategy, while effective in achieving short-term goals, is not the driving force in building the long-term capacity or institutional change necessary to build a sustainable transition. It is still an open question whether the institutional change occurred was qualitative or just incremental.

Moreover, while I find support for my fourth hypothesis that engagement in third-sector intermediary led, strategic capacity seeding arrangements diminishes the role of the public, it is not clear as to whether the City would have engaged the public if CEP wasn't involved. While CEP did not promote the involvement of the public, neither did the City or the local stakeholders. The bigger question is whether involvement of the public would have resulted in a different ordinance or a different policy process, to which we find no definitive answers. What we do see is that CEP did not initially recognize the importance of public engagement but may be taking steps to improve this. Here we see our case study again reflecting the literature and the mixed support for the inclusion of the public in the policy process.

In Atlanta's case, the presence of CEP, and the accompanying resources, facilitated Atlanta's ability to pursue and pass the building energy efficiency ordinance. Without CEP, it is unlikely this policy would have ever been passed, suggesting that CEP has a stronger role than other local niche actors, such as Southface. However, it is not clear that NRDC or IMT played a stronger role in achieving the policy goal than the support of Atlanta's Mayor. On the one hand, CEP was influential in navigating any political barriers to the ordinance as well as establishing the political support necessary. On the other hand, the most influential voice in the policy process was still the Mayor- a dynamic that existed before the presence of CEP. Our research, while limited to one case study, suggests that the presence of the third-sector intermediary may be more influential in achieving a specific policy goal when compared to local niche actors, but it does not suggest that the intermediary's presence displaces any of the previously established power structures. Which in terms of building a national sustainable transition, may be a limiting factor.

4.10 Limitations and Future Research

When research on the CEP commenced, the initial goal was to understand the role, strategy, and impacts of the third-sector intermediaries in sustainable transitions. As the project progressed, it became clear that the arrangement established by the CEP was new in the space of third-sector actors, specifically the strategy of capacity seeding and narrowed policy agenda focus. This recognition provided the motivation to do an in-depth case study. However, this one case study can be representative of all instances. What is needed is greater attention to the third-sector intermediaries and the strategic capacity seeding model specifically as it relates to using networked cities as a means to pursue national sustainable transitions.

Future research should expand the scope of research to multiple localities, with different power structures and political dynamics, that are engaging in third-sector intermediary, strategic capacity seeding arrangements in order to both challenge the existing regime and collectively push for sustainable transition. Moving forward the focus should be on comparing and contrasting how institutions are changed under these arrangements and whether these changes local begin to pressure of national institutions. Additionally, the research should focus on understanding how intermediaries are influencing and shaping the policy process for localities under different power dynamic, i.e strong-mayor and weak-mayor systems, and, to what degree localities are increasingly looking towards national and international intermediaries for policy direction and capacity support as opposed to State or Federal agencies to develop niche innovations. Future research should also explore the tradeoffs between the large, centralized third-sector intermediary in the local policy process against the use of smaller, local third-sector actors. Additionally, more is needed in understanding many of the questions presented in this paper, specifically what these arrangements and strategies means for public participation in the policy process, locally and globally.

Additionally, within the City Energy Project, more research is needed. Ten cities engaged in the first round of the CEP and round two is slated to begin in 2017 with ten additional cities. Studying how the capacity seeding strategy plays out in these difference local contexts will strengthen the understanding of which dynamics within the governance structure are driving the policy process.

Moving forward, I aim to continue the research and evaluate how other cities' involvement in the CEP has shaped local institutions and the process of developing niche innovations. From a collective view, the implications may be very different for the potential of this local governance model to facilitate a national sustainable transition.

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4.12 Appendix

Table 4-2 Summary of Semi-Structured Interviews

Interviewee	Affiliation	Number of Interviews
Matt Cox	City Energy Project-Atlanta	5
Denise Quarles	City Energy Project-Atlanta	2
Megan O'Neil	City Energy Project-Atlanta	1
Kimi Narita	City Energy Project-NRDC	1
Robert Reed	Southface-Atlanta	1
Sarah Boren	USGBC- Orlando	1
Chris Castro	City Energy Project-Orlando Staff	2
Shelby Busso	Central Atlanta Progress	3
Britany Sellars	City Energy Project-Orlando Staff	2
Lauren Zullo	City Energy Project-NRDC	1
Amberli Young	City Energy Project-IMT	1

Table 4-3 Summary of Attended Meeting

Meeting	Location
City Council Meeting to Discuss EE Ordinance	City Hall-Atlanta
City Council Meeting to Discuss EE Ordinance	City Hall-Atlanta
City Council Meeting to Discuss EE Ordinance	City Hall-Atlanta
CEP Meeting to Discuss Research Opportunities	Web Meeting
CEP Meeting to Discuss Research Opportunities	Web Meeting
City Council Meeting to Discuss EE Ordinance	City Hall-Orlando

CHAPTER 5. NICHE POLICY INNOVATIONS IN LARGE-SCALE WATER RESOURCE PLANNING: THE ROLE OF NICHE ACTORS AND LEGAL LOCK-IN

5.1 Introduction

Water systems, throughout the world, are facing major challenges due to increasing uncertainties caused by climate change, expanding population growth, and growing competition over scarce resources. To respond to these growing pressures, water resource management must transition from the current regimes to more sustainable regimes. This implies a paradigm shift in water management from command and control to a management regime that accounts for the environmental, economic, institutional and cultural characteristics of river basins and seeks to include stakeholders at all levels into the management of river basins (Hollings, 1998; Lee, 1993; Pahl-Wostl, 2016).

Throughout the world there are thriving examples of water resource management moving away from a technocratic, agency-driven and top-down policy approach to a more collaborative, adaptive, and bottom-up approach that includes the input of multiple stakeholders (Sabatier, 2005). In fact, the social science literature is now populated with hundreds of case studies on water resource management regimes that are actively seeking collaboration between diverse stakeholders and striving for greater incorporation of democratic-decision making. From the literature, several themes have emerged, some of which the majority of scholars are in agreement on, while others remain debated. The first is the assessment that a collaborative, democratic process to policy making will be more successful than a process dominated by a single government agency with little or no room for public engagement (Sabatier, 2008). The second is the assessment that a localized approach to resource management that facilitates a bottom-up process will create a more successful and sustainable process compared to a top-down approach (Ostrom, 2009; Sabatier, 2005; Norton, 2015). The third is a recognition that the variable of scale, both geographically and politically, plays a major role in shaping resource governance. (Layzer, 2008; Ostrom, 2009; Norton, 2015). It still remains a question among the major thought leaders in the space as to whether a bottom-up and collaborative approach can be effective when the natural resource in question crosses multiple geographic and political boundaries. Some scholars even question whether collaboration and public participation at a large-scale setting is actually an improved approach to water resource management compared to traditional institutions (Layzer, 2008).

However, if water systems are to respond to the growing economic, social, and ecological pressures of society, change cannot be isolated to small-scale resource management. As such there is a need in the literature to examine the dynamics of collaborative, more democratic approaches to large-scale resource management. Additionally, while the literature is full of case studies examining and testing theories on the institutional dynamics of successful local water resource management, very little attention has been paid to interstate water resource management, which institutional constructs may facilitate or inhibit a more democratic approach, and whether these institutions transfer across scales. As tensions over the sustainable transition of our water resources rise across the country and across the world, it is critical to understand how institutions frame the governance and management of stressed resources and how those institutions may support or inhibit a more democratic process.

Over the past forty years, the states of Georgia, Alabama, and Florida have been engulfed in a long-standing water resource management crisis over the Apalachicola-Chattahoochee-Flint (ACF) River basin. These tri-state 'water wars' have evolved into a complex multi-faceted interaction of political, economic, and social realities deeply enmeshed in the water system. The rapidly growing urban population in Atlanta, Ga coupled with agricultural, fishing, and recreational demands, as well as growing environmental concerns are putting massive pressure on the states' ability to manage the water supply. Worsening the situation is the recurring and increasing periods of drought, which have severely impacted water supply and water quality on the ACF.

However, in the face of mounting external pressures, the three states have not responded to the ongoing crisis with improved collaboration or democracy. Rather, the three states have clung to a centralized, highly political approach to water resource management, characterized by federal litigation and institutional lock-in. Where other river basin conflicts throughout the country have led to the development of new institutions for resource management, the tristate water-wars have largely been a story of state actors' refusal to collaborate and reliance on the old regime. Despite attempts at cooperation with a mandated river basin compact and calls from Georgia legislatures to develop a better framework for conflict management, the dependence on the courts and the legal battle endures. Now in its third decade of legal battles with little resolution.

Over the last decade, amidst endless court cases that have restricted the influence of non-privileged legal parties, there has been a growing desire by the public for greater collaboration and democratic decision-making for the management of the ACF. This sentiment is articulated by the establishment of the non-state actor, the ACF Stakeholders (ACFS). The ACFS is a localized grassroots effort, motivated to incorporate collaboration and democratic decision-making into the management of the ACF. The ACFS was established in 2009, after the recognition that the years of legal battles and continued competition over resources, dominated by power-plays by the presiding states, would never result in a sustainable or equitable management strategy.

Now, eight years later, the ACFS is still working to integrate local stakeholder views into the management plans of the basin, create a collaborative platform and long term management strategy, and generally change the governance regime of the ACF. Unlike most case studies of incorporation of local stakeholders, the ACFS is pursuing collaboration and public participation in a large-scale resource setting that crosses multiple political and geographic boundaries. Furthermore, unlike most case studies of collaboration in large-scale settings, the ACFS was not established by a State or Federal authority – it is truly a grassroots campaign. Given the difference in scale, the institutions that support collaboration in large-scale settings may differ from their smaller-scale counterparts. Or, it may be that bottom-up in a large-scale setting doesn't work if there isn't support from the top-down. In nearly every case study of collaborative resource management arrangements at the large-scale, there is a top-down desire to integrate local and grassroots actors and facilitate collaboration. Without a top-down counterpart, it may be that grassroots actors are incapable of impacting the governance of large-scale resources. At minimum, one can expect that certain institutions must be present to facilitate such collective action in a policy process dominated by top-down, traditional institutions (Layzer, 2008).

In this chapter, I employ the multi-level perspective (MLP) framework to analyze these bottom-up and top-down dynamics and explore which institutional aspects are perpetuating the resource management regime of the ACF. I follow work done by Menarder (2011) and focus on the institutions that facilitate a bottom-up, niche innovation in a sustainable transition and the legal structures that sustain a continued top-down approach to resource management. Where in the other Chapters 2 and 3, I used the MLP framework to examine niche technological innovation and the co-evolutions which support them, in this chapter I extend the MLP framework to characterize the governance arrangement of incorporating local actors and public participation in large-scale water resource management as the niche innovation and the longstanding water resource management of the ACF as the regime. Focusing on the ACFS, this chapter explores niche actors struggle to incorporate local stakeholder involvement in large-scale water resource planning regime.

To do this, I first utilize the MLP framework to identify and organize the regime, niche, and socio-technical landscape guiding the historical management of the ACF. While there are multiple economic, social, and technical aspects of the landscape, I focus on the political and legal dynamic of the current water system regime, to understand what barriers may exist to niche innovation. After characterizing the inclusion of democratic decision-making into the management of large-scale resources as the niche experiment I turn to understanding the subsystem institutions that facilitate niche innovation. To this end, I review various bodies of policy literature, focusing on: (i) collective action in common pool resource (CPR) settings, focusing specifically on grassroots actors (ii) policy entrepreneurs and social capital, (iii) participatory democracy, and (iv) the role of science and information in institutional formation, to gain insight into what institutional arrangements may be necessary to the development of collaborative, democratic, decision-making in large-scale resource governance. From the literature, I form my hypothesis and then test my hypothesis with a case study on the development of the ACFS.

The research presented in this chapter is guided by two objectives. The first is to explore the institutional dynamics that facilitate collaboration and democracy in large-scale resource governance and compare this to the case of the ACFS. Here I focus on the following institutional elements: compromised resource, mutual trust between stakeholders, an established network and policy entrepreneur, early engagement, and the need for scientific knowledge. The second is to explore which institutional elements of the existing regime are inhibiting the niche innovation of collaboration and democratic decision-making in the governance and management of large-scale water resources.

Unraveling the complexity of transitioning large-scale water resource management towards a sustainable state continues to the be the focus of multiple disciplines. The dynamics of the ACF 'water-wars' presents an interesting and timely case to explore the sustainable transition of our water resources and specifically the role of public participation in the process. On the one hand, the resource literature argues that a more collaborative, decentralized, democratic approach to resource management should produce a more successful management process (Ostrom, 2009). And this niche approach has proven successful in small-scale water resource conflicts. However, despite the calls for a more 'democratic' approach and attempts at alternative governance mechanisms, including: the establishment of an Interstate River Basin Compact and proposals for amendments to the prevailing legal framework that guides water resource management, the states have continued to seek a technocratic, lengthy, and costly federal litigation process as the mechanism to resolve interstate conflicts. In short, the regime continues to function stably. In order for the niche governance platform of collaboration and democracy to be incorporated into the established regime, there must be opportunities within the socio-technical landscape to facilitate such innovation.

5.2 Limitations of the Research

The original goal of this research was to do a thorough investigation into the institutional dynamics that facilitate the governance innovation of collaboration and democracy in large-scale resource governance, the values and opinions of the emerging actors working to develop these innovations, and explore the dynamics of scale in sustainable transitions. My work on this goal to date has been limited. The politically sensitive nature of the ACF Water Wars caused the majority of my original interviewees to decline participating in the research and restricted the majority of my research.

I also developed and implemented a survey instrument to understand whether the opinions of the ACFS members on what institutions constitute successful resource management at the large-scale are reflective of the institutions that have been observed in small-scale collaborative, success. The survey consisted of three sections. The first section focuses on determining what institutional elements facilitate successful governance. Statements describing successful governance criteria items were developed from Ostrom's eight principles and the literature. For the second portion of the survey, understanding the institutional barriers to successful management on the ACF, the same approach was used. However, while I administered the survey to over 300 recipients, due to the political nature of the topic, I only received 25 responses – 8 of which were complete.

However, from these few responses I did gain a few insights. Of Ostrom's eight principles, the survey results find support for *clearly defined boundaries, monitoring,* and *congruence between appropriation and provision rules and local conditions* (consistency in rules both legal and operational) as being critical aspects for successful collaborative governance. Survey respondents noted that the lack of a regional governing authority, and the continual reliance on the courts as major barriers to successful resource management. Combined these results suggest that there are large structural barriers, underscoring the 'rules-in-use' regarding water rights that are inhibiting successful collaboration. This is a concept I will explore in subsequent sections of this chapter.

Interestingly, the survey respondents did not list a 'lack of penalties for breaking water use rules' as a major barrier. This suggests that penalties are less important in collaboration as consistency in the law structuring use. However, at least in so far as the initial responses show, the need for accurate scientific information seems to trump any need for sanctions and is more important than collective choice arrangements or monitoring. This runs counter to what the literature states are the benefits of grassroots actors and potentially the benefits of including the ACFS in the governance process. This also suggests that while the ACFS members recognize the importance of including a diversity of stakeholders in the governance process, ultimately the most important foundation is accurate scientific information. This, however, is not that surprising given that largely the purpose of the ACFS is to develop and disseminate that scientific knowledge. I have attached a copy of the survey instrument and the results in the Appendix.

5.3 Analytical Framework: Multi-level Perspective (MLP)

The MLP framework is useful as both an organizational heuristic to show the dynamics of sustainable transitions occur but also for its flexibility in analyzing why opportunities are created for emerging niche innovations to break through and, shape the socio-technical landscape and regime. The framework is most effective when the research integrates various theoretical strands to analyze change processes, detailing how niches and incumbent regimes are shaped by external behaviors, process, and institutions at the landscape level (Geels 2011).

In this chapter, I utilize the MLP framework to organize my analysis on the ACF but integrate multiple theoretical literatures to examine which institutional dynamics may facilitate a niche innovation.

In this chapter, the regime represents the prevailing water resource management regime of the ACF, characterized by centralized litigation and failed cooperative arrangements. The institutions, policies, and legal structures that have historically supported the regime are the subsystems in question. A governance regime that includes public participation, local stakeholders, and democratic decision making in the management is the niche innovation. At the niche level, the actors have the liberty to create radical change, with much less restriction from the regime or the landscape to address societal problems (Geels 2010). Following this logic, it makes sense that many successful case studies of cooperative water resource management exist on the local level, which could be viewed as the niche level, where grassroots innovation occurs and social coalitions have the ability to influence policy discourse and practices. However, when the niche innovation is transferred to large-scale--to a socio-technical landscape that includes the multiple and competing interests of state and national institutions--the niche actors struggles to influence the regime.

The socio-technical landscape then represents the socio-economic, cultural, and environmental context in which actors and institutions of the ACF management regime are situated. Management of the ACF is shaped by national trends, macro-economic patterns, and political cultures that are even beyond the direct control of the regime and niche (Grin et al. 2010). At the landscape level, the agendas of federal institutions such as the Environmental Protection Agency, Army Corps Engineers, and the Department of Energy, coupled with growing societal and economic concerns over climate change and resource scarcity, shape the dominant economic and political discourses, and influence the patterns of behavior within the regime. Figure 5.1 outlines the relationships between these levels.

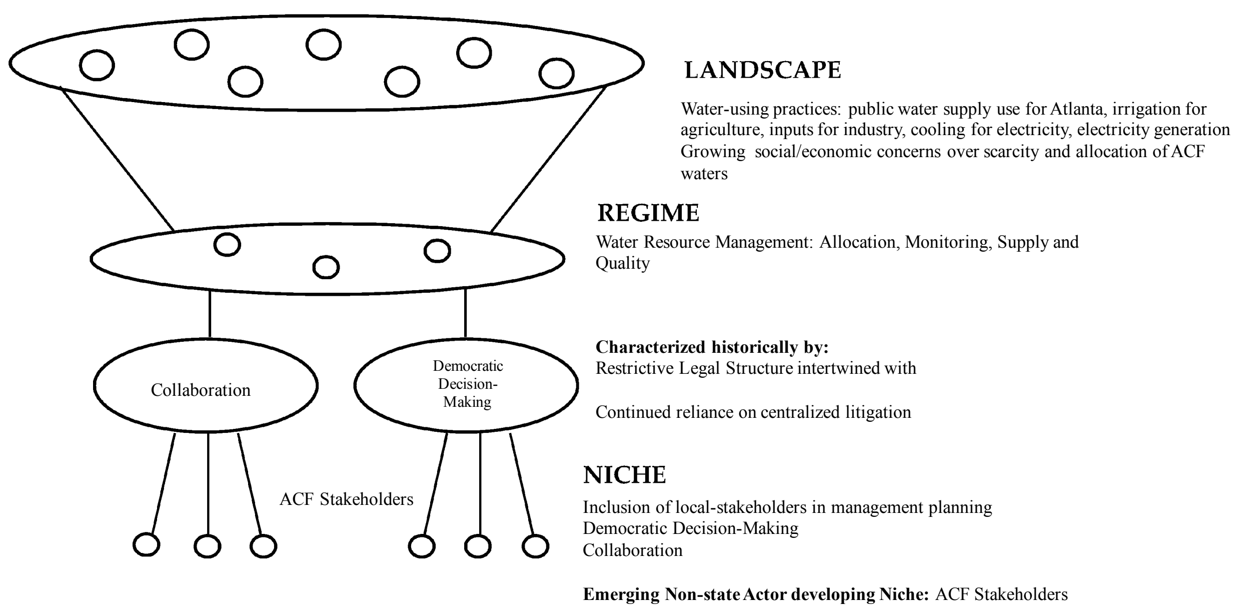

Figure 5-1 The multi-level perspective (landscape, regime, niche) and corresponding dynamics.

While the MLP has successfully been applied in historical and contemporary transition studies on water management and governance (Van der Brugge and Rotmans 2007), to my knowledge this is the first study to expand the MLP framework with the treatment of public participation in large-scale resource management as the niche innovation. The chapter brings a novel perspective on sustainability transitions in water systems through the treatment of public participation and democratic decision making in the management of large-scale water resources.

5.4 Research Questions and Hypotheses

This research is guided by the presupposition that the inclusion of democratic decision-making is critical to the sustainable management of water resources (Norton, 2016). Therefore, understanding how local actors can emerge as influences in large-scale resource management decisions will have implications for more than just the future of the ACF but is relevant for the resource literatures more broadly. The motivation of this research is to understand how to effectively scale democratic decision-making in water resource management. In my case study, I use the ACFS as a proxy to examining the inclusion of democratic decision-making into large-scale resource management. Specifically, with this research, I seek to answer one question.

Research Question: What institutional arrangements facilitate the development of democratic-decision making in large-scale resource management decisions?

Building from multiple theoretical literatures, I hypothesize that,

Hypothesis: The institutional elements of a compromised resource, mutual trust between stakeholders, an established network and policy entrepreneur, early engagement, and the need for scientific knowledge will facilitate democratic decision-making in large-scale resource management decisions.

5.5 Methodology

5.5.1 Data Sources

The paper employed primarily qualitative data from both primary and secondary sources. The primary data sources used were in-depth qualitative interviews to gain insight on the institutional arrangements that supported the evolution of the ACFS and its role in the collaborative governance process, as well as characterize the niche, regime, and landscape structures within the MLP framework. In my analysis of the ACFS, I attempted to conduct several interviews. However, I was limited by prevailing legal concerns.

I also used a wide range of secondary data sources including: legal briefs, project reports, policy documents, annual reports, project proposals, workshop proceedings, and newspaper publications to characterize the behavioral dynamics of the ACF water system and explore the current socio-technical landscape and regime barriers to niche innovation. Through detailed analysis of these documents, I explore the political, economic, social, technical, and managerial features of the ACF and explore the historical trajectory of water management, looking at the challenges for incorporating local actors and democratic decision-making into governance of large-scale resources. While the work presented is not conclusive, it does begin a much-needed dialogue on how to transition niche governance innovations across scales.

5.6 The Establishment of the Current ACF Management Regime

The Apalachicola-Chattahoochee-Flint (ACF) River Basin spans 19,800 square miles between Georgia, southeastern Alabama, and northwestern Florida. The basin includes the drainages of the Chattahoochee River and the Flint River, which meet to form the Apalachicola

River. The largest metropolitan area in the basin is Atlanta, Georgia, located in the northern section. Progressing downstream are the Cities of Columbus, Georgia and Phoenix City, Alabama. Albany, Georgia is located in the eastern portion of the basin. At the Gulf of Mexico is the City of Apalachicola, Florida. Features are shown in Figure 5.2.

Figure 5-2 Apalachicola Chattahoochee Flint Basin (Marella, et al, 1993).

For over three decades, Georgia, Alabama, and Florida have been in an interstate conflict over the management and allocation of the ACF. The management of the ACF river basin has been characterized by a regime of warring states that have favored the use of centralized litigation and power-plays to resolve resource conflict. While there has never been a history of cooperative management on the ACF, the ensuing interstate conflict over the waters of the ACF Basin began in earnest in 1986 as a result of a drought, which spread across the entire southeast region of the U.S. (Erhardt 1992; Stephenson 2000; O'Day, Reece and Nackers 2009). The 1986 drought was so severe that meteorologists accorded it the distinction of a 100-year drought, meaning that the recurrence interval of such an extreme drought was estimated to be between 100 and 200 years (Cook, et al 1988). From a socio-technical perspective, the drought spurred landscape pressures, including environmental, economic, and societal concerns, on state leaders to determine a regional management strategy for the basin.

A major impact of the 1986 drought was the reduction in Atlanta's water supply which forced a decision by the U.S Army Corps of Engineers which reshaped the historical approach to water resource management on the basin. In 1989, in order to offset some of drought's harmful effects on Atlanta, the U.S. Army Corps of Engineers (USACE) decided that a portion of storage capacity in Lake Lanier needed to be repurposed from hydroelectric production to meet the region's projected water demands (Jordan 2006).

The decision to redirect the use of Lake Lanier to meet Atlanta's public water supply needs marks the beginning of a longstanding conflict between Alabama, Florida, Georgia and other stakeholders over the management of water resources in the ACF River Basin and the current water resource management regime. Whether intentional or not, the redirect created an inherent conflict for the management of Lake Lanier and the ACF waters between managing Lake Lanier with a priority of meeting public consumption (the argument made by Georgia for sustaining Atlanta), against the historical management of Lake Lanier as primarily regulation of water ways and power production.

There were three major adverse impacts as a result of the Corps' change in reservoir operations. The first was that the temporary allocation became the de facto policy for management on the ACF and allocation of water. As a result, Atlanta did not seriously research alternative means of water supply and did not push for conservation despite its continued growth throughout the 80's and 90's. The second was that change in operations impacted the power generation schedule and generation amount from the Buford Dam. Since the Buford Dam sits at the top of a long line of Corps run dams, the impact was felt by the Southern Energy Power Administration (SEPA) which was holding the rights to sell the power generated by the releases from the Buford Dam as well as all the downstream dams.

To meet Atlanta's increased needs, the Corps continually allowed diversions from Lake Lanier and also increased the amount of water released on a continuous basis. The diversions, however, were withdrawn directly from Lake Lanier and bypassed the turbines. And the increase in continuous releases, while having the benefit of improving reliability and ensuring Atlanta's demand was met, fundamentally changed the use of the Buford Dam from a peaking generation plant. Historically, SEPA had held long-term contracts with the Corps that gave them the right to market the power produced by the dam. Before the change in operations, Buford Dam only released a small portion of the water on a continuous basis, allowing the dam operators to shore-up the reservoir and time the bulk releases to coincide with peak electricity demand. The basic idea was that by releasing during peak hours, SEPA could market the generation at higher rates. Unfortunately, as Atlanta's needs increased, so did the loss of available peaking power.

However, SEPA is required to maintain all contracts, which forced SEPA to purchase power and pass those costs on to customers, namely the Southeast Federal Power Customers.

The third major implication of the Corps' operational changes was the adverse downstream effects and implications for Lake Lanier's, as well as other reservoirs', recreational value. The diminished flow down the Chattahoochee limited the use of major flatwater recreation areas and threatened the cooling water supply for power plants in Alabama. It also created issues for barge navigation in Alabama's ports. The decreased and time-altered flows impacted the ecology of the estuary in Apalachicola, FL which hurt the local oystering and fisheries-based economies. Additionally, the changes in the pattern and timing of flows also threatened listed endangered species found in the lower reaches of the basin. Of course, all of these impacts were exacerbated by the series of droughts that plagued the southeast throughout the eighties, nineties, and into the early two-thousands, which introduced two other stakeholders into the debate- agriculture and electricity generation. Decreased flows meant less water for irrigation and cooling for thermoelectric power production. Additionally, decreased flow coupled with increased drought and warming temperatures, made it difficult to maintain the established discharge limits set by the EPD for point-source and thermal pollution.

The decision to change the management of Buford Damn and Lake Lanier created conflict in the current management of the ACF and highlighted the deep social, economic, and political differences between users as well as the need for cooperative management of the ACF water system. However, instead of moving the regime towards a more equitable and sustainable governance platform, the regime resisted transition. From the early 1990's until today, the partisans on all sides have attempted a series of forums to resolve what had become an unfavorable governance situation; however, all have continually returned to the federal court system to determine a water resource management plan. Each state continues to utilize power plays through the centralized legal structure of supreme court litigation to win control over the ACF. As explored in the next section, these entrenched power plays between the states and the Corps are supported by a legal system at the regime level that have created a lock-in by which states have become increasingly less open to collaboration and more focused on dominating the ACF through litigation (Masters, 2016).

The one exception was in the late 1990's when legal cases did not progress, and the states stayed their litigation in favor of negotiation by entering into a pair of interstate compacts, one each for the ACF and ACT. However, unlike other successful compacts in the U.S, there was no pre-negotiated allocation of the water; rather these two compacts were no more than an agreement to discuss water sharing plans. The ACF Compact established the ACF Basin Commission and charged it with the daunting task of agreeing on an allocation formula.

The goal of the compacts was to provide a comprehensive study as a guide, and facilitate negotiations between the states over a 5-year period. At the time, legal scholars hailed the ACF Compact as the best method of resolving the warring states. Unfortunately, the states were unable to reach an agreement, despite several deadline extensions. The two main points of disagreement were Florida's refusal to accept an agreement that only guaranteed minimum flows and Georgia's refusal to limit irrigated farm acreage and control reservoir levels, based on Florida's advisement.

Instead of embracing collaboration, in negotiations states attempted to alter or circumvent requirements of federal law because the states knew that the allocation formula agreed to under the compact would become federal law (Priscoli, 2009). Furthermore, federal agencies and representatives were unwilling to be bound by the decisions of the states. However, without the implementation force of federal agreement, the allocation formula would be uncertain (Sherk, 2005). Leitman (2005) argued that a lack of stakeholder involvement, a breakdown in trust, and an inadequate collaboration process were the main reasons for the failure of the ACF compact. Sherk (2005) concluded that the ACF and ACT compacts were doomed to fail because Congress was unable to act coherently and decisively to allocate interstate water resources. Mandarano (2008) notes, however, that the "experience of Congressional allocation and federal centralization of comprehensive water resources management has been problematic at best."

Feldman (2008) and Porzecanski et al (2012) concluded that the ACF compact failed because preconditions needed for adaptively managing the ACF basin were impeded by lack of a shared vision, conflicting demands, an unequal balance of authority, and separation of water quality and quantity regulations. In the end, despite six years of frustration and millions of dollars spent, the Commission never came to an agreement and the Compact expired on August 31, 2003.In many ways, it is the failure of these policy instruments that has defined the regulatory frameworks for policy formulation and water resource planning, and conflict management on the ACF.

Amidst the failed ACF Compact negotiations, Georgia, experienced its most severe drought to date and the warring factions returned to the court. At this point, levels at Lake Lanier fell to all-time lows and Georgia continued to petition the Corps to reallocate water from Lake Lanier for municipal uses in Atlanta. Frustrated by the failure of the ACF Compact and fearing substantial losses in revenues, the Southeastern Power Customers, Inc., filed its own suit against the Corps in December 2000 in the District of Columbia. Then when the Corps did not respond to Georgia's allocation request in 2001, Georgia filed suit against the Corps in the Northern District of Georgia, only to have Florida and Southeastern Power petition to intervene in the suit. Thus, despite attempts at innovation in the regime, ultimately the actors returned to litigation as the strategy for water resource management on the ACF.

And this regime remained in place from 2002- 2009, when each State, the Army Corps, and the Southeastern Power Customers all engaged in legal gymnastics over the proper allocation and management of the ACF. Alabama, Florida and Southeastern Power argued that the Corps' decision to allocate water to Atlanta was a fundamental operating change and undermined the Water Supply Act.[21] Florida argued against the Corps, citing that decreased flow rates violated the Endangered Species Act. All of this took place against increasing drought which made it difficult for the Courts to separate what was a result of Corps operations and what a result of natural strain.

Amidst the legal battles, each state also tried to engage in a series of political power-plays to gain control over the ACF. For example, in 2003 Georgia attempted to strike a separate agreement with the Corps of Engineers that allowed metro Atlanta 23% of the water in Lake Lanier, which at the time was a 65% increase. But the agreement never came into play because

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[21] O.C.G.A. §§ 12-5-470 to 482. This Act gives the Department of Natural Resources the authority to build water supply reservoirs. It authorizes DNR to acquire property and contract with local governments to begin and maintain reservoir projects that will sell and distribute water supply to local counties and municipalities. The Act specifies the powers of DNR and the relationship with local governments. The Act makes it the duty of DNR to select the site for such projects but provides for checks on DNR powers.

Alabama and Florida again challenged it in court. The Corps attempted to implement an interim plan, now weighing the requests of all angered parties, which no party was satisfied with and again more litigation ensued. Secretary of Interior Kempthorne (a former governor familiar with water disputes) even personally conducted negotiations at which he tried to obtain a settlement but left his post when Georgia and Florida were unwilling to compromise. With each suit, the position of the opposing parties hardened, making resolution and compromise impossible.

By 2007, Georgia's drought was so severe that state water restrictions were declared, including a total ban on outdoor water use in 61 North Georgia counties and a mandated 10 percent reduction in overall water use. Additionally, Georgia decided to sue the Corps of Engineers to reduce flows from the reservoir. Again, Congress intervened and Alabama, Florida and Georgia all agreed to a temporary reduction in the flow of the Chattahoochee River and to work out a long-term agreement for water sharing. However, ten years later no such long-term agreement has been reached. The willingness to negotiate with each other that was at least present in 1997 with the signing of the ACF compact, was by 2009 completely gone.

5.7 Characteristic Features of the ACF Water System Regime: The Legal Structures that contribute to decades of lock-in

The historical conflicts over the management of the ACF water system represents a mix of technical, political, institutional, and socio-economic characteristics that interact at multiple levels to create a complex and dynamic system for water supply. The existing governance approach has inherently produced a state of legal competition between users that sees the waters of the ACF as a zero-sum game, inhibiting collaboration between stakeholders, and continues to rely on federal litigation to outline management strategies (Masters, 2016). Like many resource concerns, the current management of the ACF is now dominated by asymmetrical power relationships and politics, deeply intertwined in the broader socio-political and economic context, which make water management inherently political and resistant to change (Mollinga, 2008).

While there are multiple subsystems and entrenched dynamics working to sustain the current regime, as well as multiple dynamics within the socio-technical landscape, in this research I focus on the legal structures at the regime level that have perpetuated the current regime of water resource management on the ACF. Specifically, I focus on the impacts of the riparian water laws employed throughout the Southeast.

Understanding how the riparian water law and legal doctrines shape the development and capacity of water management regime of the ACF was one of the initial goals of this research. With a limited number of relevant scholars and experts who are willing to speak with me, I turned towards reviewing publicly available legal briefs to make some sense as to how the legal structure which underpins Georgia, Florida, and Alabama's regime management is creating a lock-in approach to litigation and hindering collaboration between the warring states. For simplicity sake, I focus on water law in Georgia.

The legal doctrines establishing water rights in Georgia are based on a common law, riparian system. Prior to the 1970's, all water law was based on common law. However, recognizing the need to develop oversight (largely related to water quality) Georgia created state regulatory bodies to manage the permitting of water and to monitor water quality. While riparian law governs both ground and surface water, Georgia's law distinguishes between surface water and groundwater as separate systems of which the allocation is governed separately. The use of a riparian system and the separation of surface and ground water hold implications for both the development of water regulations and the allocation of water resources.

Under riparian laws, landowners have the right to the water on and adjacent to their land. If the water is used for natural use, meaning private use with no commercial gains, there are typically no associated fees or payments for use. However, if the water is used for commercial gains (i.e. agriculture or thermoelectric) permits and an associated fee may be required. The use of water under riparian law is essentially unlimited except when the water supply is deemed insufficient to satisfy the reasonable needs of all adjacent landowners. In such a case, landowners are supposed to reduce their use in proportion to their rights – sometimes based on the amount of adjacent land they own (CBO, 2006). The resulting incentive is to own more land; generally, the more land a party owns, the more that party has control over and access to available water resources.

The Georgia law of riparian rights was well summarized in the case of Price v. High Shoals Manufacturing Co. The Price court stated, (Supreme Court of Georgia, 1915) "Every riparian owner is entitled to a reasonable use of the water. Every such proprietor is also entitled to have the stream pass over his land according to its natural flow, subject to such disturbances, interruptions, and diminutions as may be necessary and unavoidable on account of the reasonable and proper use of it by other riparian proprietors. Riparian proprietors have a common right in the waters of the stream, and the necessities of the business of one cannot be the standard of the rights of another; but each is entitled to a reasonable use of the water with respect to the rights of others. What is considered reasonable use is a question for the jury, in view of all the facts in the case, taking into consideration the nature and use of the machinery, the quantity of water used in its operation, the use to which the stream can be applied, the velocity of its current, the character and size of the water course, and the varying circumstances of each case."

From early on, Georgia's establishment of a riparian system recognized the courts' authority and precedent in determining 'reasonable use.' While there was less need for interstate legal disputes in the early 1900's, the basic precedent of seeking the courts as the mechanism for handling water disputes has been set for some time. Until the mid 20th century, most issues (if any) regarding the management of water resources was left to the courts. In 1964, the Georgia General Assembly established the Water Quality Protection Act to govern the use of surface water. In 1977, the Georgia General Assembly amended the Water Quality Protection Act of 1964 (WQPA) and established a revocable permit system to govern large users of surface water. Since then, the WQPA has been amended a number of times but remains the primary legislation governing surface water allocation in the State today. The WQPA is enforced almost exclusively by the Georgia Environmental Protection Division (EPD).

Under the WQPA, users withdrawing, diverting or impounding surface water in quantities greater than 100,000 gallons per day on a monthly average are required to obtain a permit from the EPD. The General Assembly has established a set of factors that EPD must consider in the evaluation of permit applications. These factors represent many of the same factors that courts previously considered in evaluating the claims of a riparian owner, essentially codifying the reasonable use doctrine established at common law.

The WQPA distinguishes between farm and non-farm uses, and the nature of the use will determine both the scope and duration of the permit. All non-farm uses are subject to evaluation under reasonableness criteria established by EPD. The duration of permits for non-farm uses may range from ten to fifty years. Non-farm permits may be suspended or modified if it is determined that the quantity of surface water allowed to be withdrawn under the permit is either (1) greater than needed for the use upon which the permit was based; or (2) interferes with the reasonable use of another applicant; (3) in violation of the law or with the health and safety of citizens. The WQPA also has a set of environmental regulations that comply with the Federal Clean Water Act. The two federal laws governing pollution are the Federal National Pollutant Discharge (NPS) control programs, which include the Nonpoint Source Management Program established by the 1987 Clean Water Act Amendments, and the Coastal Nonpoint Pollution Program established by the 1990 Coastal Zone Act Reauthorization Amendments.

During periods of extreme shortfalls, the Georgia Environmental Protection Division (EPD) may issue emergency orders, which modify the terms of existing permits. The WQPA requires EPD to make an effort to notify affected permittees in writing and provides those permittees five days to appear before EPD and object to the proposed action. During such emergency periods of water shortage, EPD must "give first priority to providing water for human consumption " (EPD, 2012).

One of the major issues that legal scholars raise with Georgians' Common Law Riparian Water Rights Doctrine is the concern over the sale and use of water. Currently, under the Law, possessing a piece of land accompanies possession of all encompassed water sources. Under this system, landowners are prohibited from selling or transferring this water out of their watershed, unless with adjoining land. Unlike Western States that allow for the short-term transfer of water rights and permits, Georgia has no formal structure for allowing the sale or shift in water permits from one user to another without the sale of the land. This creates a very inflexible system and one that makes it difficult for the EPD to encourage utilizing water for the most ‘necessary’ uses in time of water stress.

Another major concern is the definition of ‘reasonableness.’ While the EPD may have limited authority on defining the reasonableness of use and the designation of a permit, it does not have clear authority on how that permit may change in future scenarios of resource scarcity. Essentially, what may be deemed reasonable in 2002 may not be reasonable in 2052. This is exacerbated by the fact that under a Riparian system the use of the water is not required to keep the right alive. New uses may be started at any time as long as the new use is a reasonable one. Because the right is attached to the riparian land, non-use does not extinguish the right.

Georgia, like most riparian states, have enacted some form of a permit system, moving towards what has been described as a “regulated riparian” system. Regulated riparianism allows for a permit system to allocate water usage. Each state that uses a form of regulated riparianism has a central state agency with the control to say who may use the water, how much they can use, and when they can use it. However, unlike other states, Georgia still largely leans on common law when framing how to handle future water use. Under a fully regulated riparianism framework, and departing from common law riparianism, state authorities must examine the projected use before any water is ever actually used. A regulated riparian framework may use the same reasonable use criterion as with the common law but determine beforehand if the new use is reasonable. This allows the state to take into account both the potential benefits to society and the compatibility with current uses before granting a new permit.

Another major concern of the common-law riparian system, is that it limits the ability for the EPD to amend or restrict water usage in the state. Under a regulated riparian system, the regulating authority can adjust the quantity of water allowed under permit to be in line with the public interest. This does not necessarily necessitate a time of extreme shortage, as it does in Georgia. Rather the acting authority must prove that it is in the best interest of the public to redirect use. Furthermore, under a common-law system, permits are often granted for a much longer period of time, making it difficult to amend if necessary and plan accordingly.

The Southeast is not alone in having a history of water strife. This country is fraught with contentions over resources, usually involving interstate water sources, trans-basin diversions or both, for centuries. However, where the Southeast differs from other parts of the country is in its continued reliance (despite developments of river basin compacts and decentralized governance platforms) on federal adjudication for any and all conflicts. In part this is due to the nature of the competing and fragmented authority over interstate waters which, according to Abrams (2008), require "major changes in the underlying state laws governing water allocation."

There is something to be said about how the current, legal structure, underpins an unwillingness to compromise. Georgia's common law riparian model inherently pushes states away from oversight and towards opposition. Over the past fifty years, a number of northeastern states have replaced common law riparianism in favor of regulated ripariansim. The push towards regulated riparianism was fueled by desire to not be in a case-by-case, conflict-by-conflict, and after-the-conflict-has-arisen adjudication of the common law. As Abrams (2016) articulates the shortcomings of a riparian system, "first, private property rules are ineffective at producing the maximum set of benefits from a common pool resource. Second, managerial allocations offer the possibility of precise quantification of right and thereby the possibility for increased security of right. Third, managerial systems are proactive rather than reactive."

Recently, Georgia law makers have recognized the benefits of moving towards a more regulated riparian model as a source of creating flexibility in permitting and planning. This was made evident by proposals in the Georgia legislature, regarding the Flint River Basin Drought Protection Plans. The legislature proposed to revise the permitting system to allow the EPD to modify certain water permits, mandate application efficiencies, and authorizing the state to fund augmentation projects. However, the bill failed to pass in the House. And that failure highlights an issue that has underscored the water wars and interstate water resource management more broadly in Georgia.

The failure to create major change in the legal underpinnings of water resource management was also present during the 2003-2004 Legislative Sessions, when the Georgia legislature recognized the need to address the looming interstate resource concerns as well as devise some sort of planning for future use. The Georgia General Assembly passed HB 237 – the Comprehensive Statewide Water Management Planning Act – which required the state to develop a statewide water plan that considered long-term goals in delineating methods of resource management. The Joint Comprehensive Water Plan Study Committee was then created and given the task of developing the framework for this plan. Responsibility for assembling this plan was shared with the EPD with oversight from the Georgia Water Council (GA Water Planning).

The plan was intended to accomplish a wide variety of objectives, including: determine a means for settling disputes with neighboring states, protect the environment, and regulate water quality and quantity (GA State Univ. Law Review). While originally, HB 237 included measures to address water planning issues such as inter-basin water transfers and water permit sales, these measures were unfavorable politically and would require changes to legal statute and the author of the bill removed those elements. That being said, in a white paper to Georgia's Comprehensive Water Plan in 2002, the Georgia Chamber of Commerce further claimed that laws needed to be more anticipatory so that there is a system for limiting water usage during water shortages (GA Chamber of Commerce).

Despite attempts with the legislature to amend the management of the ACF, the State of Georgia has either continually refused or been unable to address a systematic shortcoming of Georgia's legal institutions shaping water resource management. And in an absence of new regulations, new water laws, or an authority to specify the contours of water allocation, and in the absence of a framework by how these reallocations can be negotiated with neighboring and affected parties, there is little room to believe the regime will change.

The legal structure underpinning the current regime is also intertwined with the policy institutions at the landscape level that shape the regime dynamics. The riparian system creates a major barrier for the federal institutions, like the Supreme Court, to change the regimes' approach to water resource management. Historically, the most prominent of interstate suits before the U.S. Supreme Court is for the equitable allocation of a water resource. However, most of these lawsuits have arisen in the West, where the legal doctrine of prior appropriation is in place and the court has recognized that the doctrine gives it guidance. In Georgia, Alabama, and Florida no such clear rule governs because of the nature of riparian rights as being correlative and not fixed. In fact, until the recent water wars, the Supreme Court had really only decided two interstate water allocation disputes from the East-Connecticut v. Massachusetts and New Jersey v. New York. And both cases were decided over seventy years ago, and within a short time of each other. As a result, neither case gives firm guidance about what principles the Supreme Court would apply to divide water bodies between two states that adhere to the riparian rights system.

The recognition that the legal underpinnings of the current regime are sustaining a management approach that utilizes litigation and power-plays over democratic decision-making is also made evident by the failed attempts at negotiation and cooperative management strategies. The demise of the ACF and ACT compacts has been well described by Sherk (2005), Leitman (2005), and Feldman (2008). Sherk (2005) noted that the compact required the federal representative to determine that the proposed allocation formula be consistent with federal regulations, something the federal commissioner found impossible to do.

5.8 The Niche: Opposing the Regime

The failures of the regime to resolve water resource conflict on the ACF, triggered a niche experiment. In 2009, recognizing that litigation processes had been unable to resolve conflict, a grassroots effort, the ACFS was launched by a few individuals and groups most impacted by the interstate conflict. Now, seven years later, the ACFS is an extremely diverse group representing all sectors in Georgia, Florida, and Alabama with members representing 4 sub-basins that extend through Georgia, Alabama, and Florida-the Apalachicola Basin, the Flint Basin, the Lower/Middle Chattahoochee Basin, and the Upper Chattahoochee Basin (See Figure 5.3). A list of all the interest groups as well as the governing board members is found in the Appendix.

The primary purpose of the ACFS remains to develop a Sustainable Water Management Plan for the basin. In fact, it was after decades of fruitless litigation that the ACFS formed, in large part, out of the recognition that the judicial process was not working to create a sustainable management strategy, and there was a great need for public involvement (Masters, 2016). While the ACFS is working toward a consensus-based vision, this process has been challenging.

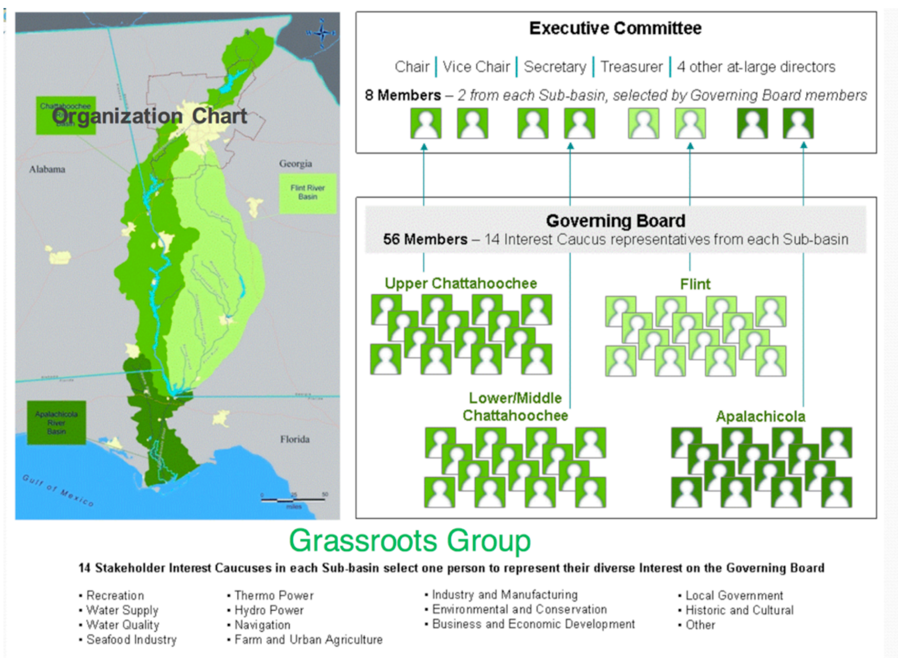

Figure 5-3 ACF Organizational Chart

In subsequent sections I will explore the dynamics of the ACFS but for now it is important to recognize that the ACFS exists today solely out of the public's recognition that the current regime was insufficient in handling the multiple social, technical, environmental, and economic facets of water resource planning and out of the public's recognition that collaboration and democratic decision-making is imperative to create a sustainable management platform. Following sentiments expressed by Norton (2016) whether or not the niche innovation that the

ACFS is working so hard to incorporate into the regime actually affects the management of the ACF it is clear that the establishment of the ACFS (in and of itself) is marked change in society's view of resource management and represents a qualitative shift in its behavior.

5.9 Understanding the Institutional Dynamics that Support Niche Innovations in Large-Scale Water Resource Management

It is clear that continued frustration over the regime dynamics prompted action by the public (characterized by the ACFS) to push for niche innovation. However, frustration alone does not make a transition. In the subsequent section I turn my focus to understanding the institutional dynamics that facilitate the inclusion of collaboration, democratic-decision making and grassroots actors in the management of natural resources, with the purpose of understanding what institutional aspects of the current niche and regime may be necessary for transition.

In *Governing the Commons*, Elinor Ostrom (1990) sought to develop a series of empirical studies of groundwater basins to provide a "broader theory of institutional arrangements related to the effective governance and management of common-pool resources (CPR)." Ostrom argued that several social groups have struggled successfully against threats of resource degradation by maintaining localized, self-governing institutions and provided examples of sustainably and unsustainably managed meadows, forests, irrigation systems, groundwater basins, and fisheries. Ostrom argued that people are able to cooperate and manage natural resources jointly if supported by specific institutional arrangements. Her conclusion was that successful CPR management institutions share certain institutional aspects. Ostrom's list of eight design principles, or "essential elements," for successful CPR management include 1) clearly defined boundaries, 2) congruence between appropriation and provision rules and local conditions, 3) collective-choice arrangements, 4) monitoring, 5) graduated sanctions, 6) conflict-resolution mechanisms, 7) minimal recognition of rights to organize, and 8) nested enterprises (p. 90).

However, Ostrom did not argue that these institutional aspects are specific rules for success, rather they compose a set of design principles that characterize all robust CPR institutions (Ostrom 1990) and describe the broad structural similarities among self-organized systems that have been able to adapt and learn so as to be robust and resilient to many social, economic, and ecological disturbances that occur over time (Eggerston, 190). The "primary role of the design principles is to explain under what conditions trust and reciprocity can be built and maintained to sustain collective action in the face of social dilemmas posed by CPRs. This collective action, in turn, helps prevent the deterioration of a managed CPR" (Cox et al. 2010).

Over the past 30 years, CPR scholars have compiled numerous empirical examples of the emergence of self-governing collaborative resource institutions (Baland & Platteau, 1996; McCay, 2002; National Research Council, 1986; Ostrom, 2001; Ostrom et al., 1994). Within this large body of empirical research, the literature has identified key characteristics of both the resource and the resource users that are likely to support collective management (Ostrom, 2001). The literature has built upon Ostrom's argument and argued that the success of the resource management depends upon additional institutional arrangements, including the congruence of ecosystem and governance boundaries, the specification and representation of interests, the matching of governance structures to ecosystem characteristics, the containment of transaction costs, and the establishment of monitoring, enforcement and adoption processes at the appropriate scale (Eggertsson, 1990; Ostrom, 1990; Bromley, 1991; Hanna, 1992; Hanna and Munasinghe, 1995). Since 1990, a substantial volume of literature has amassed debating the usefulness and validity of Ostrom's (1990) design principles.

While there has been substantial support for the principles, some scholars have criticized their theoretical grounding when applied to large resources and questioned whether it is still unclear whether all of Ostrom's principles translate across scales (Cox, 2010). The CPR literature is largely limited to small-scale settings with easily defined boundaries, stable resources, and homogenous, users. And case studies of successful implementation of CPR management can be characterized as still existing at the niche-level. At the regime level – with a larger number of conflicting users, various types of stakeholders, and a greater geographic scope – it is unclear whether the conclusions of the CPR literature will translate. As Ostrom recognized (2009), given that many studies have focused on locally managed resources settings, a critical area of research is to understand the governance of larger scale resources, by analyzing "relationships among multiple levels of these complex systems" (E. Ostrom, 2009, p. 420). Logically, however, many of the key institutional arrangements necessary for small-scale CPR management can be applied to large-scale settings. I focus on the following aspects of CPR literature-trust between stakeholders, a history of interaction among actors, and the ability to establish cross-scale institutional linkages to reduce the transaction costs of interactions among diverse stakeholders.

Among the institutional arrangements that facilitate grassroots stakeholder engagement and that support collective action, trust and reciprocity are considered to be essential (Ostrom, 1998). Indeed, many have recognized that trust and a perception of fairness between stakeholders are essential ingredients in the success of any collaborative effort (Welsh and Gray 2002). In CPR settings, trust facilitates interaction and knowledge transfer and can work in concert with a number of other factors (Libecap, 1994; Ostrom, 1990; Taylor & Singleton, 1993). Consequently, trust is enhanced when CPR users have experience working together directly (Ostrom, 1990; Taylor & Singleton, 1993).

Additionally, Ostrom and others have often emphasized the importance of nesting smaller common-property systems in larger and still larger ones. The primary argument being that there is a high probability that the social systems have cross-scale physical relationships when they manage different parts of a larger resource system, are polycentric in nature, and thus may need mechanisms to facilitate cross-scale cooperation (Lane and Scoones 1993, Niamir-Fuller 1998). There is a difference between nested, polycentric situations (Berkes and Folke 1998, Berkes 2002, Yandle 2006, Cinner et al. 2009) and situations which contain multiple levels of horizontal organization that mirror each other (Coward, 1977).

Inherent in the concept of 'nestedness' is the understanding that there is a need for linking action situations at smaller scales, such as local CPR user groups, with those at the regime level, such as state or federal bodies. These linkages may be established through institutions, which can include shared rules and strategies, or regularized patterns of interaction, creating functional interdependencies between different actors, or collective bodies (Young, 2002). Cross-scale institutional linkages connect actors that are polycentric and function at different scales or levels of social organization or political jurisdiction. While other scholars use different terms than "linkages", the concept of diagraming cross-scale connections across or between actors, organizations, or collective bodies that have distinct scales or scopes of authority, are found throughout the literature (Adger, Brown, & Tomkins, 2006; Berkes, 2002; Carlsson & Berkes, 2005; Pinkerton, Wilson, Nielsen, & Degnbol, 2003; Wilson, Ahmed, Siar, & Kanagaratnam, 2006).

The underlying reason why creation of trust and cross-scale linkages are likely to support cooperative and democratic management platforms comes from transaction cost theory. Transaction costs involve the time, money, and effort associated with searching for collective partners, bargaining with those partners, as well as monitoring and enforcing agreements (Taylor & Singleton, 1993). CPR scholars have long recognized that certain characteristics of the physical environment as well as the stakeholders involved in the decision-making process can reduce the transaction costs associated with collective action, and thus increase the likelihood that resource users will devise new institutional arrangements (Libecap, 1994; Lubell et al., 2002; Ostrom, 1990; Taylor & Singleton, 1993). However, the literature has also recognized that there must be some element of urgency and feasibility, for collective management to work. More parties are likely to benefit, and thus, be interested in collaboration, in situations where problems are relatively severe (Lubell et al., 2002), yet where improvements are still feasible (Ostrom, 1990, 2001).

5.9.1 Participatory Democracy Models

"Solving shared problems together on behalf of a shared place is the essence of democracy" (Kemmis 2001 p. 153).

Over the past decade, the research into participatory and discursive democratic theory models has largely focused on assessing the public stakeholder and public participation. These assessments have largely been responses to the failings of traditional pluralism and liberal democracy's lack of democratic deliberation and public participation on environmental issues (Fischer 2000; Foster 2002; Schlosberg 1999; Weber 1998). Both Weber and Schlosberg describe an imperfect pluralist process dominated by national environmental groups and exclusive of the grassroots (Schlosberg 1999; Weber 1998).

Against this backdrop, new deliberative approaches, particularly in the watershed management space, are advocated for a revitalization of the public sphere in which citizens voluntarily deliberate on social and environmental issues. Such, 'discursive designs' placed value on non-hierarchal decentralized approaches to power and regulation over centralized approaches (Barber 1984; Dryzek 1990; Fischer 2000). Frank Fischer praised citizen participation as the "touchstone of the democratic system" (Fischer 2000 p. 37). Such models stood in contrast with liberal representative democracy, which is distinguished by bureaucratic decision-making and participation that is almost exclusively dominated by interest group participation that often alienates the grassroots (Barber 1984; Dryzek 1990; Fischer 2000).

Accompanying the advent of deliberative democracy in environmental policy, were assessments and theories on the public's role in policy development and decision-making. According to Fisher (2000), citizen participation contributes three important goals: participation implies thoughtful deliberation of socially significant issues; participation "legitimizes policy development and implementation;" and participation can contribute to "professional inquiry" (Fischer 2000 p. 2).

Additionally, it became widely recognized that there is inherent value in public participation in environmental collaboration, including the strengthening of community, understanding, and skills as a consequence of citizen's deliberation on regional and local issues (Born and Genskow 2000; Snow 2001; Weber 2003). Born and Genskow observed, "the ability to positively affect problem-solving capacity, with an emphasis on increased ability to implement proposed solutions within the socioeconomic, cultural, and political context of a particular watershed, is one of the most significant features of new watershed approaches" (Born and Genskow 2000 p. 47). As Putnam (1993) recognizes, public participation improves the social capital of community networks which helps to further facilitate coordination and communication and amplify information about the trustworthiness of other individuals (Putnman, 1993).

While the benefits of public participation were clear to many, the process of engaging public participation and the institutions necessary to maintain a discursive democratic system was hardly straightforward and was further challenged by increasing complexity of environmental problems and inherent equity concerns. As Foster (2002) points out, the avenues to power are through economic means, political standing, and access to technical expertise, all of which potentially discriminate against grassroots actors (Foster 2002). The ability to engage with other stakeholders of often varying interests and expertise becomes critical for public participation (Webber, 2003).

Specifically, Fischer writes, "speaking the language of science, as well as the jargon of particular policy communities, becomes an essential credential for participation" (Fischer 2000 p. 23). It is also clear from the participatory literature, that the stage in which citizens engage in the policy process impacts their role and function. Engagement early in the decision-making process establishes a voice for public participation and helps to solidify trust between different actors (Busenberg 2000; Duram and Brown 1999). As Lubbell (2005) recognizes, trust between stakeholders is imperative in order for public participation to be meaningful and sustained (Lubell, 2005).

5.9.2 Policy Entrepreneurs and Social Capital

Policy entrepreneurs are influential individuals who promote and influence policy changes and are key to developing niche innovations (Baumgartner & Jones, 1993; Kingdon, 1995). Political entrepreneurs can aide in solving collective action problems within groups by changing beliefs, incentives, or resources of individuals in order to promote cooperation to achieve collective ends (Taylor, 1987). Policy entrepreneurs can include actors within and outside of the traditional government sources of influence and power, including policy elites, citizens, or experts. While much of the entrepreneurship literature focuses on the individual as an entrepreneur, scholars have demonstrated that groups also have the ability to act as entrepreneurs. Due to their size, greater resources, and political influence, these groups can at times be more influential than individuals. For the purpose of studying the ACFS, the policy entrepreneurs are defined as the initial group of grassroots advocates for the development of the ACFS who have invested their resources – network, knowledge, time, energy, reputation, and sometimes money – in the hope of future policy change or action (Kingdon, 1990).

The literature on collaboration natural resource management has continually recognized the importance of policy entrepreneurs and leaders in facilitating institutional change. Blomquist (1992) was among the first to document policy entrepreneurs as leaders in facilitating institutional change and recognize entrepreneurship as vital element for collective action in CPR settings. In addition to leveraging individual resource, policy entrepreneurs play a key role in agency-level collaboration in managing natural resources and ecosystems (Thomas, 2003). As

(Heikell, 2005) notes, the efforts of policy entrepreneurs are likely to enhance collective action when they work in conjunction with other factors, such as experience working together, trust, and frequent communication. The result is an entrepreneur's' ability to provide the initial and ongoing, social-capital necessary to facilitate collaborative management (Lubell & Scholz, 2001). Lubell (2004) finds that this is particularly effective when entrepreneurs are helpful to facilitate the collaboration between agencies and individual resource users.

In addition to their ability to promote cooperation, the literature has keyed into the entrepreneurship's ability to leverage 'external resources' relevant to policy change (Busenberg, 2000). In particular, entrepreneurs' can provide the resources identified as important to policy change – time, energy, expertise, knowledge, and reputation (Kingdon, 1990; Roberts & King, 1991). It is the network that accompanies an entrepreneur that will determine its level of engagement. The entrepreneur's ability to provide the greatest access to human capital is its key value in the process and in achieving outcomes (Florress et al., 2001). And while entrepreneurs influence the process, the literature is clear that they do not control it (Roberts and King; Mintrom, 1997). Rather, entrepreneurs are seen as more autonomous, flexible, political risk-takers that can "generate creative policy solutions, redesign governmental programs, and implement new management approaches" (P. J. King & Roberts, 1992, p. 173).

The entrepreneurship literature has also recognized the unique role of grassroots actors. Grassroots policy entrepreneurs play a critical and unique role in the policy process, particularly in their ability to easily leverage social capital and form strategic partners for state or federal institutions seeking to accomplish policy objectives in often contentious situations (Lowery, 1998). In studying grassroots policy entrepreneurship in watershed management, Lubell (2004,

353) notes that, “the interaction between local government representatives and grassroots stakeholders is the crucible in which social capital is formed.” As a result, the continued engagement of grassroots entrepreneurs and traditional government structures expand the social capital necessary to reduce the transaction costs of collective action and leverage policy change. Grassroots entrepreneurs effectively leverage their initial social capital to engage in the policy process and through continual engagement build the social capital necessary facilitate long-term cooperation.

5.9.3 The Role of Technical Information

Developing a common understanding of policy problems across stakeholders is contingent upon building core values or beliefs between the different groups. This is especially critical when attempting to develop a niche innovation in a sustainable transition. When core values are more closely aligned, stakeholders are more likely to work with each other (Sabatier and Jenkins-Smith,1993). How stakeholders develop core values is influenced by many factors but one factor that is continually recognized in the empirical literature is the access to scientific or technical information. The empirical literature shows that collaboration is better facilitated across differing groups when there is access to technical information for debate as technical information can both illuminate a new policy problem and provide solutions (Cobb & Elder, 1972; Kingdon, 1995; Walker, 1977). As such, technical information is a critical component in facilitating collaboration between stakeholders. The empirical literature on collaborative resource management efforts have shown that collective agreement among stakeholders on problem definition supports the development of these institutions (Koontz et al., 2004; Wondolleck &

Yaffee, 2000). In small-scale CPR settings, it is easier to acquire accurate information about the conditions of the resource.

Recently, this debate has gained momentum through growing interest in ‘‘knowledge transfer/exchange’’ between knowledge producers and users. Although this has traditionally focused on one-way transfer of knowledge, interest is shifting towards more collaborative knowledge transfers and the joint production of knowledge. This research focuses more on how the exchange of different types of knowledge between multiple stakeholders influences the decision-making process (Phillipson and Liddon, 2007). While the integration of technical and local knowledge is often both political and difficult, (Rhoads, 1999; Korfmacher , 2001) there is recognition that when blending different types of knowledge, local knowledge , while complementary, is ultimately subordinate to expert technical and scientific knowledge (Smit, et al., 2015).

Additionally, technical information helps to clarify the physical components of a policy problem and define the physical scope of a resource management problem as well as define which actors are most impacted by different policy pathways. Similarly, technical knowledge can help stakeholders to understand who benefits from a change in policy, who is harmed and to what end (Heikell, 2005). Looking at grassroots stakeholders through the lens of the firm theory, and knowledge-based views of the firm, technical knowledge is seen as a key competitive asset for any interested party and allows actors to create strategic alliances (Grant and BadenFuller, 1995; Conner and Prahalad, 1996). To that end, technical information can be likened to a type of social capital that can help facilitate the policy process by both bringing different stakeholders together to exchange knowledge as well as define the policy problem.

When looking at the CPR management literature, the participatory democracy literature, the policy entrepreneur literature, and the informational literature together, many key elements become clear. First it is clear that a foundational trust between differing stakeholders is necessary for grassroots actors to engage in collaborative governance decisions. Additionally, a common understanding of the physical conditions of the resource is key to facilitating dialogue between grassroots actors and other stakeholders. It is also apparent that ‘grassroots’ actors can serve as critical links within in a collaborative, nested governance structure and across different institutional aisles. From these observations, the logic is that a grassroots organization’s ability to influence a collaborative governance process is predicated on its ability to garner the trust of other stakeholders, form strategic cross-scale linkages, leverage social capital, and facilitate engagement between diverse stakeholders. See Table 5.1 for a summary of these conclusions.

Table 5-1 Summary of the Literature

	LITERATURE	CONCLUSIONS
INSTITUTIONAL ARRANGEMENTS	Common Pool Resource Literature	• Established Trust Between Stakeholders • Ability to create linkages between actors • Nesting smaller systems management into the large resource governance • Element of urgency • Feasibility of management or policy decision
	Participatory Democracy Literature	• Understanding the language of science, as well as the jargon of particular policy communities • The stage of engagement • Early engagement in the decision-making process • Trust between stakeholders
	Policy Entrepreneur, Social Capital Literature	• Presence of Policy Entrepreneur to leverage existing network • Established social capital that is valuable to other stakeholders • Connection between agency actors and users
ROLE OF GRASSROOTS ACTORS	The Role of Technical Information	• Provides the ability to define scope of problem and policy impact • Technical knowledge may supersede local knowledge • Technical knowledge as a competitive asset that provides leverage in the • Collaborative process

In terms of what institutional dynamics help facilitate the development of collaboration and democratic decision-making (niche) in large-scale resource management (regime), the literature presents a number of scenarios. It is clear that there must be a specific compromised resource and that resource must be salient to actors. Additionally, we support for the idea that early engagement in the decision-making process establishes a voice for grassroots participation. Recognizing that grassroots actors can serve a specific role of providing scientific and technical information, this suggests that the lack of information may be a prerequisite. Again, we see the importance of trust between stakeholders as necessary to the formation and long-term inclusion of grassroots organizations in the policy process.

In terms of what role(s) a grassroots actor may play in the large-scale collaborative process, in other words how to incorporate the niche at the regime, it is reasonable to assume that to maintain a seat at the decision table the ability to address the specific language and technical content of the discussion and early engagement is valuable. Accurate information increases the likelihood of local stakeholders creating CPR institutions (Ostrom, 1990), whereas differences in information about the resource can make it difficult. To that end, in situations where accurate information on the condition of the resource is available, more collective action will occur and those stakeholders facilitating the access to information will have an important role in the decision-making process. Likewise, given that technical knowledge can be leveraged throughout the policy process to both define the scope of the policy problem as well as bring diverse stakeholders together, the ability to provide and share technical knowledge can be viewed as a valuable form of social capital. Combined, an effective role that grassroots actors may play in a large-scale process would be as a source and network for technical knowledge.

Hypothesis: The institutional elements of a compromised resource, mutual trust between stakeholders, an established network and policy entrepreneur, early engagement, and the need for scientific knowledge will be present when grassroots actors are included in large-scale water resource management process.

5.10 Reconciling the Literature with Reality: Assessing the evolvement of the ACFS and Niche Governance Innovations

In this section I reconcile a few of the institutional elements identified in the literature with the creation and ongoing inclusion of the ACFS in the governance process. As noted, I use a case study on the development of the ACFS as a proxy to understand the institutional dynamics that facilitate the niche innovation of collaboration and democratic decision making in the management of large scale water resources.

While initially I hoped to conduct more interviews to gain a better understanding of how the formation of the ACFS compared with the literature, due to the political context, many members of the ACF as well as other actors within the sociotechnical regime - including the Army Corp of Engineers, SEPA, and the EPD - were unable to speak with me.

5.10.1 Compromised Resource Conditions and Salience of Resources

Studies of CPR and the formation of grassroots organization highlight that users are compelled to engage in resource management when the resource in question is under stress, or certain users feel they are being denied their adequate use of the resource, i.e. the salience of the resource. To begin my examination with what institutional drivers may have led to the establishment of ACFS, I examine both the physical state of the ACF and the salience of the resource to the founding members.

The ACFS began with the purpose of creating a better management resource system for a river basin that spanned hundreds of miles of ecologically diverse watersheds, hosted multiple competing users, and where millions of people also lived. The ACF is, in itself, a major source of economic and social well-being. With the recognition that there were multiple, competing needs on the ACF, and the belief that the current management strategy was not adequate, the ACFS commenced. As one member put it, “we basically just wanted to see if the stakeholders, without the lawyers, could create a better management strategy (Masters, 2016).”

The ACFS formed at two critical points in the water wars history. First, as noted, in 2003 Georgia struck an agreement with the Corps of Engineers to provide metro Atlanta with 23% of the water in Lake Lanier, which at the time was a 65% increase. Because Alabama and Florida challenged the agreement in court, Atlanta was in some degree of limbo over its water resources. This limbo became acutely problematic when the drought returned to Georgia in 2006. From 2006 to 2007 the drought intensified and water levels in Lake Lanier plunged toward historic lows, resulting in Georgia suing the Corps of Engineer to reduce flows from the reservoir. Water restrictions were declared across the region; the Federal Government chose to intervene. When State and Federal efforts to broker a tri-state agreement by March 1, 2008, failed, the Corps took it upon itself to determine a new management plan. By December of 2007, Lake Lanier had reached an all-time low. At which point, the Corps had already been managing five federal ACF reservoirs under an Exceptional Drought Operations (EDO) amendment. The EDO lowered the minimum flow requirement for the Apalachicola River, reducing the rate of storage drawdown if drought persisted and allowing reservoirs to refill before normal operations resume. On ACF there are four species protected by the Environmental Species Act, all of which depended on these flows. Concern over the impact of low flows to these species began to heighten, causing tension between State, Federal, Corps, and environmental leaders.

In response to the growing frustration and conflict, the Georgia Assembly approved funding for a statewide water management plan including a 3-year data gathering effort to determine how much water is available in the state. At the same the time the US Court of Appeals overturned the 2003 agreement between Georgia and the Corps of Engineers increasing the water supply from Lake Lanier for metro Atlanta. The ruling stated that such a reallocation requires Congressional authorization. Any transparency between States on crafting a water management plan essentially disappeared.

The physical and legislative fragility of the ACF helped the ACFS founders engage other stakeholders and competing resource users. The original ten founders started holding stakeholder forums throughout the basin, which confirmed both the frustration with the litigation process and a desire to collaborate. Within six months, the ACFS grew from 10 to 35 volunteers representing all 4 regions of the ACF Basin and various, often competing, interest groups. What is very important to understand, and a key element that makes the case of ACF Stakeholders so interesting, is that unlike other cases water resource management stress and challenge (such as the Colorado River, Chesapeake Bay, or the Delaware River Basin) there was no mandate for the ACFS establishment. While the court order provided a sense of legitimacy and urgency to the ACFS and its role in the water wars, it did not establish or legitimize the grassroots organization’s role in the policy process. The court order gave a timeline for the ACFS to leverage when engaging with other stakeholders and a sense of urgency for determining a new management strategy. The combination of a legal need and urgency for a long-term management plan opened a door for local, stakeholder engagement and the space to begin building a governance strategy, with the inclusion of grassroots input.

Immediately following the formation of the ACFS and as the founding members began gaining support, in July 2009, a Federal District Court judge ruled that the water supply was in fact not an authorized purpose for Lake Lanier and gave the governors of Alabama, Georgia and Florida three years to settle their differences and negotiate an agreement for water allocation, again creating a window for legitimacy and need for the ACFS. Without such an agreement, water supply would revert to 1970s levels by 2012 and Metro Atlanta could lose up to a half of its water supply from Lake Lanier and the Chattahoochee River.

Interestingly enough, by the end of 2009 the drought began to subside, alleviating much of the immediate panic and creating another window for planning. At this point the ACFS had established itself as a grassroots organization focused on creating a collaborative process focused on developing a resource management plan. While drought and failure in the state negotiation process prompted the original members to form the ACFS, the ACFS began engaging other stakeholders when the drought had subsided enough to pull the states out of crisis mode and turn greater attention towards long-term goals. The drought that sparked the intense judicial engagement, was subsiding as record-breaking floods returned Lake Lanier to full pool. The physical stability, albeit short-term, allowed for stakeholders to engage in conversation about the sustainability of the resource as opposed to shoring up immediate needs (Masters, 2016).

5.10.2 Established Network and the Existence of a Policy Entrepreneur

While establishing at a time when tensions with the current system were high helped the ACFS emergence, the network of the founding members facilitated the initial engagement with other parties and was able to establish the ACFS as a platform for multiple, and often competing, users.

The original ten members had different backgrounds; each was frustrated with the current management practices; and given the state of the ACF felt an element of urgency to try and establish a better platform. In the initial year of the ACFS, each founding member committed to leveraging their own professional network, as well as seeking out and inciting other affected parties to the table (Master, 2016). Unfortunately, I was not able to acquire the necessary interviews with the original founding members to establish how their network was leveraged or whether or not there was a specific policy entrepreneur in the group. However, from my conversation with the current Director for the ACFS, it was apparent that each of the founding members brought with them a network of individuals relevant to the policy debate.

5.10.3 Need for Technical Information and Scientific Knowledge

One issue that all members of the inaugural members of the ACFS agreed upon was the need for better data on the past, current, and future state of the ACF under growing demand. Only through accurate technical information would the ACFS be able to devise a better management strategy for the Basin. To that end, analyzing the ACF and producing data on the resource conditions was a prominent goal, and continues to be so, on the agenda. The ACFS continually recognizes its core goals as:

- *Develop a consensus-based, basin-wide vision and a unified voice for the ACF Basin.*
- *Enhance communication among all stakeholders in the ACF*
- *Develop and disseminate a common, scientifically valid understanding of the ACF Basin, including the inter-related nature of water management in the Basin, the needs of all of its stakeholders, and the limitations of the system*
- *Recommend and help implement solutions that are based on the best available technology and science*[22]

While data and information on the existence of resource problems was relatively widespread in the years leading up to the inception of the ACFS, the data was disaggregated and had not been applied to any master management strategy. Much of the research on the ACFS had come through either the Army Corp, which the ACFS felt was not representative of all the needs in the Basin, or the USGS and were focused on increasing threats to local ecosystems, limited supply, and long-term drought (Light, et al., 2006). Furthermore, just because the information on degrading ecosystem conditions, increased drought, and strained conditions did not mean that consensus existed on the cause of the problems or the solutions to these problems (Masters, 2016). The ACFS acutely realized a need for a consensus-based management plan, and set off to create one.

As a result, the ACFS spent much of 2010 gaining stakeholder input and membership and by the Spring of 2011 had developed a scope of work document for a Statewide Management

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[22] ACF Stakeholders Update. Sustainable Water Management Plan. Business of Water Conference. Phoenix City, Alabama. October 22, 2015. http://www.troy.edu/phenixcity/assets/documents/cwre/2015-presentations/Webb-Betty.pdf

Plan (SWMP). To accomplish this study the ACFS needed funding, and again the founding members leveraged their network towards the fundraising effort. By the fall 2011, the ACFS had initiated a contract with Black & Veach and Atkins to begin drafting the timeline and needs of developing a SWMP.

By determining the need for technical information, committing to creating the forum and to developing a SWMP, and pursuing third-party consulting, the ACFS asserted itself as playing a critical role in the water wars, as the entity with technical information. This approach has led to multiple iterations and updates of resource management plans, and in essence, new policies for addressing the problem. Additionally, by taking on the role of providing technical information, the ACFS provided a way to institutionalize the collaboration between the scientific community and with other stakeholders. The ACFS became the forum by which concerned stakeholders of all interests and the scientific community were engaged. And this was done without a State or Federal order supporting the efforts.

The key take-away, however, is that despite the ongoing debates and disagreement about how best to resolve the resource problems along the ACF, the pursuit of collaboration in itself, and the ability to produce information and awareness about the nature and extent of the resource management problems was the source of institutional formation and evolution for the ACFS. This point has theoretical and empirical support from the literatures. Where the breakdown is that despite information playing a critical role in the formation of the ACFS, as well as the benefits of collective choice more broadly, these factors do not necessitate institutional change.

ACFS has developed the data and information articulating the presence of the problem and a management solution. However, this has yet to lead to a change in the governance strategy of the ACF, i.e. the legal battles ensue. More work is needed to understand the limit by which technical information influences the governance process.

5.10.4 Trust between Actors

Assuming the role of providing technical knowledge and developing a resource management plan did not come without pushback, internally and externally. To date the ACFS is still dealing with political and legal battles over their pursuits to create a SWMP. Interestingly enough, despite external conflicts, there was a significant amount of trust between ACFS members. Not all members agreed but there were no alliances formed between members of the ACFS that would not have been obvious by their represented interests. For the most part ACFS members largely stuck to their platform of interest and did not attempt to form any alliances with other members to leverage any power (Master, 2016).

In large part this was a result of the formal structure set up by the ACFS. Every member received no more than one vote and every formal decision had to be supported by unanimous consent. (Master, 2016) The established structure resulted in a "fairly democratic process and one where everyone understood that people were there for their own interests but we had to be honest with each other (Master, 2016)"

5.11 Discussion

While my ability to collect interviews from ACFS members and do research on this active topic has been limited, I do find initial support for aspects of my hypothesis. The compromised condition of the ACF as well as the growing frustration over the presiding governance strategies were the main impetus for the formation of the ACFS. Recognizing the lack of collaboration and lack of scientific-knowledge driving the governance approach, the purpose of the ACFS became establishing a platform for mutual collaboration and the development and dissemination of technical knowledge to support a consensus-driven management plan. Ultimately the purpose of the ACFS remains to develop and integrate a new management approach to the ACF, and to provide the warring states with a consensus-based, management plan, in hopes of ending the fruitless legal battles. To develop this niche innovation, the ACFS worked to establish institutions that would foster trust among participants, represented by the single vote system and the requirement of unanimity in decision-making. Additionally, the ACFS committed to being the source of scientific knowledge, as represented by its commitment to research and independent analyses.

However, in terms of timing of engagement, the ACFS only became active after decades of legal battles between the states. This may be a reason for why the platform and the resources that the ACFS provides is not being utilized yet by the warring states. The regime lock-in may be too entrenched, and at this point in the process, the idea of incorporating collaboration and democratic decision-making threatens the ability of the regime actors to utilize power plays to dominate the ACF system. The lack of early engagement may prove to be a hindrance to the success of the ACFS but this particular case study is unable to determine if early engagement would have produced a different outcome. It is still unclear whether or not the ACFS, the platform for collaboration as well as all of the wealth of knowledge it provides, will be utilized effectively in the governance of the ACF. It could be the case that the years of federal litigation have created a path dependency for Alabama, Georgia, and Florida, despite the opportunity provided by the ACFS.

To date, this research suggests that the institutional elements of a compromised resource, mutual trust between stakeholders, an established network and policy entrepreneur, and the need for scientific knowledge, support the incorporation and relevance of grass root actors, increased public participation, and democratic decision making in water resource management. Furthermore, there are hundreds of successful case studies of collaborative resource management regimes at the small-scale. However, despite the success at the niche level of innovation, and despite the presence of multiple, facilitating institutions, the ACFS has yet to impact the prevailing water resource regime. What is unclear is whether the timing of engagement is the limiting factor for the inclusion of the ACFS in the management of the ACF, or if the institutional elements that facilitate small-scale success simply do not transfer to the large-scale. From my review on the legal subsystems that have supported the current regime, it appears that even the best efforts of grassroots actors may be suppressed by the regime in the absence of fundamental changes to the water laws in the Southeast. Without qualitative change to the legal structures which guide the ACF water system it is unlikely that any qualitative change will occur in the management of the basin.

If the goal is for Georgia to move towards a more equitable sharing of scarce resources, create a structure for collaboration and greater adoption of democratic decision making, as well as have some foresight on how to plan for changing resource conditions, at minimum a reexamination of the water rights and the distribution system is necessary. Continuing to follow a purely common law riparian system, without the managerial authority to allow for flexibility or the inclusion of relevant information, seems to underpin the current regimes' path dependency towards inevitable legal dispute.

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5.13 Appendix

5.13.1 ACF Stakeholders

The Interest Groups Represented by the ACF Stakeholders Include:

- Water Supply
- Farm and Urban Agriculture
- Recreation
- Local Government
- Water Quality Industry and Manufacturing
- Navigation
- Historic and Cultural
- Hydro Power
- Environmental and Conservation
- Seafood Industry
- Thermal Power
- Business / Economic Development

The individual associations that belong to the ACFS include:

- Alabama Municipal Electric Authority
- Alabama Rivers Alliance
- Apalachicola Riverkeeper
- Arcadis-US
- Atlanta Fulton County Water Resource Commission
- Atlanta Regional Commission
- Calhoun County Board of Water Commissioners
- Camilla Chamber of Commerce
- CCT & Associates, Inc.
- Chattahoochee Riverkeeper
- City of Atlanta City of Camilla
- City of Cumming
- City of Dothan
- City of Gainesville
- City of Griffin
- City of LaGrange
- City of Sandy Springs
- Clayton County Water Authority
- Cobb County Water System
- Cobb County-Marietta Water Authority
- Columbus Water Works
- Conservation/Recreation Lands, LLC
- Council for Quality Growth
- D J Plastics
- Dougherty County Farm Bureau
- Emory University
- Flint Riverkeeper, Inc.
- Florida Riparian Stakeholders
- Forsyth County Water & Sewer
- Friends of Lake Eufaula
- Georgetown – Quitman County Commissioners
- Georgia Conservancy
- Georgia Green Industry Association
- Georgia Municipal Association
- Georgia Poultry Federation
- Georgia Power Company
- Golder Associates, Inc.
- Gulf County Board of Commissioners
- Gulf Power Company
- Gwinnett County
- Gwinnett Environmental and Heritage Center Historic Chattahoochee Commission
- Jim Woodruff Preference Customers
- Jones Ecological Research Center
- LaGrange-Troup County CoC

- Lake Lanier Association
- Lake Seminole Association
- Liberty County Board of Commissioners
- Liberty County Riparian Stakeholders
- MeadWestvaco
- Metro Atlanta Chamber of Commerce
- Metro North GA Water Planning District
- Middle Chattahoochee Water Coalition
- MillerCoors LLC
- Mitchell County Board of Commissioners
- Mitchell County Development Authority
- Mitchell County Farm Bureau
- National Peanut Buying Point Association
- Nature Conservancy of Georgia
- Neal Land & Timber Co.
- Oglethorpe Power Corporation
- Pelham Chamber of Commerce
- Procter and Gamble
- Riparian County Stakeholders Coalition
- Riverway South
- Robert B. Ragland Foundation, Inc.
- Southeastern Federal Power Customers, Inc
- Southern Aluminum Finishing Co.
- Stansbury Resolutions by Design, Inc
- Southern Nuclear Operating Co.
- SunTrust Bank
- TOTO USA
- Tri Rivers Development Association
- Troup County Board of Commissioners
- Utilities Board Tuskegee
- West Point Lake Coalition

5.13.2 Methodology Materials

5.13.2.1 Interview Questions

The following are the interview questions developed for meetings with relevant parties regarding the ACF Stakeholders.

- How well experts perceive the current water management system on the ACF to be working?
- What characteristics expert think are necessary for the successful management of interstate river basins, including Ostrom's eight principles?
- What were the motivations for the current polycentric approach to management on the ACF?
- What institutions are driving the current approach to water management and what institutional barriers may exist to achieve successful management?
- What role do energy institutions play currently in the management of ACF?
- What is/has been your role in working with water resources on the ACF?

Physical Settings:

- Can you characterize the economic value of the ACF?
- Who is ultimately responsible for the ACF management?
- What physical and human resources are required to manage the ACF?
- What technologies and processes are required for management?
- What are the resources required for successful management?
- What physical restrictions dictate management?

Attributes of the Community

- What cultural attributes challenge water resource management on the ACF?
- What cultural challenges could prevent the states from relying on decentralized, management?
- Do you think the public is well informed of the issues?
- Existing Institutional Setting (including nested enterprises)
- How well are federal, state, and local activities coordinated?
- What was the motivation for establishing the ACFS and pursuing greater decentralization in management?
- Have any of these motivations been actualized?
- What rulings have set the most precedence in governance approaches on the ACF?
- What legal challenges could prevent the states from relying on decentralized, management?
- How does the local management of water resources work with state and federal management of water resources?
- How much authority do local, decentralized actors actually have in the decision-making process?

Transaction Costs

- Transactions costs includes the costs of including multiple levels of governance and multiple stakeholders in the management of interstate river basins, do you think are the major transaction costs to the current management approach?

- How well does the information that has been provided by expert scientists, responsible for modeling the ACF dynamics, match with the governance strategies that are currently playing out on the ACF?
- What are the benefits to the current management approach? What are the costs?
- Rules in Use (including well-defined boundaries, monitoring, granulated sanctions) :
- Are there clear rules that specify the set of positions or roles that each level of governance plays?
- Are there clear rules for establishing water rights? Or stakeholder rights in the management process?
- Are there clear rules that govern water rights, energy contracts, and energy generation decisions?
- Do the penalties of enforcing water management increase with the severity of the offense?
- How would the ACF conflict be different if Georgia, Alabama, and Florida were not riparian states?
- How has the riparian system shaped the water allocation? Data collection? Stakeholder involvement?
- How role has the riparian system played in shaping the way interstate river basin management has developed in the south?
- What legal doctrines are setting precedence in this allocation and management conflict? Who are the according responsible parties?
- Are there currently clear boundaries of use on the ACF? What role does the legal system play in this?
- How often is litigation used to settle local disputes, and interstate disputes?

Adaptability

- Is the current management approach sustainable to long-term consumption patterns, development needs, and potential for increased drought?
- Are there benefits of a more decentralized governance system?

The Role of Information (including the congruence between appropriation and local condition)

- How often scientific analysis discussed by stakeholders?
- To what extent are decisions guided by local knowledge? Scientific knowledge? Or determined by hierarchal decisions?
- How are local concerns over drought or watershed resilience reflected in the organizational plans?
- Are all decisions made, in regards to governance, based on scientific evidence? What proportions of decisions are based on scientific information? Who are the according stakeholders?
- How much time, if any is dedicated toward exploring alternative means for meeting demand? In what sectors are these mostly impacting?

Stakeholder dynamics (including: minimum recognition of rights, and conflict resolution mechanisms)

- How was ACFS formed? Why?
- What were the incentives to forming ACFS?
- What is the meeting format?
- How often does ACFS meet?
- What is the selection process?
- What is the retention rate?
- What areas of consumption (i.e. agriculture, energy, public supply) have been at the center of discussions over curtailing use? Why do you think this is?
- How are local concerns over drought or watershed reflected in stakeholder interests?
- How are decisions made?
- What happens if there is conflict between stakeholders? How is it resolved?
- What are the major institutional barriers to successful interstate river basin management on the ACF?
- How are decisions presented to State and Federal entities?
- What policy levers do stakeholders have? How are they used?
- Does the current system allow for representation of all interests?
- Are there rules to how much information can be shared between stakeholders?

Cross-scale Actors (Focus on Army Corp and SEPA)

- What role does water availability play in energy resource planning?
- At how many scales of governance are energy institutions operating?
- Do energy institutions play a larger role in decision-making on the ACF then other stakeholders? Including federal energy and private energy?
- Have their ever been discussions about shifting sources of energy generation to curtail water? Has there been any analysis done on this?
- What are the major institutional barriers to successful interstate river basin management on the ACF?
- How have years of unmet contracts influenced the marketing of SEPA power?
- How are SEPA contracts set? What actors have control?
- Has there ever been an instance where SEPA operations or Southern Power were amended due to external pressures?
- Are there clear rules for how USACE manages Lake Lanier in times of drought or how Southern Company manages generation in times of drought?

Some examples of high-level questions for USAEs include:

Action Situation:

- What concerns, if any, do you have about future SEPA operations conflicting with ecological concerns or development requirements?
- To what extent do concerns over drought influence your management decisions?
- Existing Institutional Setting:
- To what extent do you provide feedback to SEPA representatives on operations?
- What other stakeholders are USAE in constant communication with?
- To what extent to you have input on the setting of SEPA contracts?
- To what extent have SEPA contracts caused conflict with other stakeholders invested in watershed management?
- How has the relationship between USACE and SEPA changed overtime?

Rules in Use:

- How do legal doctrines shape USAE operations?
- How do federal environmental standards shape operations?
- Transaction Costs:
- Are there any transaction costs associated with shifting generation strategies?

Some examples of high-level questions for SEPA contract recipients:

Action Situation:

- To what extent do you provide feedback to SEPA representatives on operations?
- To what extent to you have input on the setting of SEPA contracts?
- To what extent have SEPA contracts caused conflict for your constituents?
- To what extent do concerns over drought influence your contract decisions?
- Existing Institutional Settings and Rules In Use:
- How has the relationship between your city and SEPA changed overtime?
- What concerns, if any, do you have about future SEPA operations conflicting with ecological concerns or development requirements?
- What is the primary reason and benefit for securing a SEPA contract?
- Are there alternatives?
- Transaction Costs:
- What barriers may prevent an alternative approach?
- Are there any transaction costs associated with shifting generation strategies?
- Some examples of high-level questions for Georgia Power and Oglethorpe Power Cooperation include

Action Area:

- How long has water supply on the ACF been a concern?
- What concerns, if any, do you have about future Georgia Power operations conflicting with ecological concerns or development requirements?
- To what extent do concerns over drought influence your management decisions?

Existing Institutional Setting:

- How have the 'water wars' impacted operations?
- What role is Georgia Power or Oglethorpe Power Cooperation playing in the decision making of state and federal governance decisions on the ACF?
- What other stakeholders are you in constant communication with?
- How has the relationship between you and USGS, EPD, and USACE changed overtime?

Rules In Use:

- What penalties do you receive for not complying with water management laws? How many have you received? Do these influence your decisions?
- How do legal doctrines shape your operations?
- How do federal environmental standards shape operations?

Transaction Costs

- Are there any transaction costs associated with shifting generation strategies?

Additional

- Do you think that other people share your opinion?
- What do you think is the future of the ACF system?
- Overall, how do you think the management system is working? Explain? What do you think are the characteristics that describe successful water management institutions? Are those present on the ACF?
- Is there anyone else you would recommend I speak to about this topic?
- What do you think is the level of trust between local, state, and federal entities?

5.13.2.2 Methodological Approach to the Administered Survey

In-depth semi-structured interviews with leaders among the ACFS members were used to gain insight into the characteristics that stakeholders felt important in successfully managing water resources in the ACF and to explore how well new actors engaged in the policy process believe the current system is working. Additional interviews were scheduled to included representatives from local, state, and federal water-related agencies, non-state actors, municipal, energy, industrial, and recreational interests within the basin. Unfortunately, due to the political sensitivity of the topic area, after first agreeing to be interviewed, all but two interviewees declined.

Insights from these two interviews were combined with insights gleaned from work presented in Section 1 as well as Ostrom's success criteria (Ostrom, 1990) and operationalized into an online survey. The survey consisted of three sections. The first section focuses on determining what institutional elements facilitate successful governance. Statements describing successful governance criteria items were developed from Ostrom's eight principles and the literature. All statements were positively worded (Belson 1981; Foddy 1993) because they are more reliable than negatively worded items (O'Muircheartaigh et al. 2000). For the second portion of the survey, understanding the institutional barriers to successful management on the ACF, the same approach was used. Before administering the survey, three cognitive surveys were conducted (Lietz, 2010) to test how well respondents will comprehend the survey questions. These cognitive surveys were administered to fellow grad students. The third portion of the survey allowed the participants to freely comment on their involvement in the policy process.

The first section of the online survey allowed participants to systematically rank twenty-one statements on the most important aspects of successful water resource management, with 1 representing the aspect that the participant found to be the most important aspect of successful water resource management. The twenty-one statements were:

1. Clearly defined water rights
2. Clearly defined rules of use
3. The costs and benefits of water use are allocated equitably among users
4. Accurate scientific analysis on physical restrictions
5. Clear understanding of the costs and benefits of different allocation plans
6. Incorporation of local knowledge to state and federal resource management decisions
7. Monitoring of water use
8. Collection of data on water use
9. Penalties for not complying with management decisions
10. Penalties are reflective of the severity of the offense
11. Flexibility in the decision-making process
12. Ability for all levels of stakeholders to influence policy decisions
13. The inclusion of multiple and diverse stakeholder input
14. Coordination between local, state, and federal management entities
15. Preservation of ecological habitats
16. Insurance of adequate supply for agricultural production
17. Insurance of adequate supply for energy production
18. Insurance of adequate supply for city water supply
19. Insurance of adequate supply for recreational use
20. Insurance of adequate water conditions for fishing industry

The second section of the online survey allowed participants to systematically rank twenty-one statements on the barriers to successful water resource management, with 1 representing the aspect that the participant found to be the largest barrier to successful water resource management. The twenty-one statements were:

1. Maintaining environmental standards
2. Unmetered surface water consumption
3. Lack of consistency in legal rulings regarding water rights

4. Historical legal constraints related to the riparian legal system
5. Uncertainty about future water supply under different climate scenarios
6. Lack of involvement from city management
7. The need to insure adequate water conditions for fishing
8. The need to insure adequate water supply for agricultural use
9. The need to insure adequate water supply for energy production
10. The need to insure adequate water supply for Georgia cities
11. The need to insure adequate water for recreation
12. The need adequate water for recreation
13. Poor cooperation between state leaders
14. Uncertainty about future water demand
15. Lack of transparency in the decision-making process
16. Lack of clear rules or boundaries for water users
17. Lack of public participation in resource management decisions
18. The rules for water use allocation are not fair to all users
19. Lack of penalties for breaking water use rules
20. Lack of technical knowledge supporting decision making
21. The rules governing water resources do not match the demands on the water users
22. Inability for those impacted by changes to water resource management to participate in the decision-making process
23. State and Federal decision-makers respect for local knowledge
24. The complexity and/or costliness of the decision-making process
25. Lack of coordination between local, state, and federal decision makers

To sort and analyze the firsts two portions of the survey responses, I chose to use a Q-Sort Method (Zeemering 2009, Thomas and Watson 2002). The Q-sort method is used in environmental policy research in order to gain insight into policy discourse centered on natural resource and environmental problems (Addams and Proops 2001) The Q-Sort method tests the item agreement and the fit in order to form the basis for assessing the construct validity and to improve the reliability of the constructs (Nahm et al. 2002) and is particularly useful when researchers wish to understand and describe the variety of subjective viewpoints on an issue. The Q-methodology employs a factor analysis to identify the common patterns in which statements were sorted, using the eigenvalues as a percentage of explained variance to determine the major factors. A varimax rotation was then employed to obtain the final factor solutions (McKeown and Thomas 1998). This is in line with many Q-sort methodologies (Zeemering 2009).

5.13.3 Copy of Administered Survey

RespondentID
CollectorID
StartDate
EndDate
IP Address

LastName
Custom Data
Please Select an affiliation
Please Select an affiliation - Other (please specify)
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Maintaining environmental standards
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Unmetered surface water consumption

Copy of Administered Survey (Continued)
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of consistency in legal rulings regarding water rights
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Historical legal constraints related to the riparian legal system
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Uncertainty about future water supply under different climate scenarios
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of involvement from city management
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The need to insure adequate water conditions for fishing

Copy of Administered Survey (Continued)
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The need to insure adequate water supply for agricultural use
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The need to insure adequate water supply for energy production
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The need to insure adequate water supply for Georgia cities
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The need to insure adequate water for recreation
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The need adequate

water for recreation *Copy of Administered Survey (Continued)*
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Poor cooperation between state leaders
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Uncertainty about future water demand
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of transparency in the decision-making process
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of clear rules or boundaries for water users
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of public participation in resource management decisions

Copy of Administered Survey (Continued) Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The rules for water use allocation are not fair to all users
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of penalties for breaking water use rules
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of technical knowledge supporting decision making
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The rules governing water resources do not match the demands on the water users

Copy of Administered Survey (Continued)
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - State and Federal decision-makers respect for local knowledge
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - The complexity and/or costliness of the decision-making process
Please rank the issue that you believe to be the largest barrier to successful water resource management on the ACF, with 1 representing the largest barrier. The recommended way to rank your choices is to first go through and pick the largest barrier from the list of 25 choices. Then sequentially pick the largest barrier from the remaining choices. - Lack of coordination between local, state, and federal decision makers
If there is a barrier(s) you believe is not included in this list, please list it below. - Open-Ended Response
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Clearly defined water rights
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The

Copy of Administered Survey (Continued)
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - The costs and benefits of water use are allocated equitably among users
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Accurate scientific analysis on physical restrictions
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Clear understanding of the costs and benefits of different allocation plans
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Recognition of the importance of local knowledge into the decision-making process
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Incorporation of local knowledge to state and federal resource management

decisions *Copy of Administered Survey (Continued)*
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Monitoring of water use
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Collection of data on water use
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Penalties for not complying with management decisions
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Penalties are reflective of the severity of the offense
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Flexibility in the decision-making process

Copy of Administered Survey (Continued)
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Ability for all levels of stakeholders to influence policy decisions
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - The inclusion of multiple and diverse stakeholder input
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Coordination between local, state, and federal management entities
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Preservation of ecological habitats
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The

Copy of Administered Survey (Continued)
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Insurance of adequate supply for energy production
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Insurance of adequate supply for city water supply
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Insurance of adequate supply for recreational use
Please systematically rank the most important aspect of successful water resource management. With 1 representing the aspect you believe to be the most important. The recommended way to answer this question is to first pick the aspect you think is most important and then systematically go through and rank the most important aspect from the remaining list. - Insurance of adequate water conditions for fishing industry
If there is an aspect(s) that you believe is critical to successful water resource management, please list below. - Open-Ended Response
• I believe that energy production is the most important issue driving the management of the ACF
• I believe water use allocation for energy production should take precedence over water use allocation for agriculture
• I believer water use allocation for energy production should take precedence over

Copy of Administered Survey (Continued)
• I believe water use allocation for energy production should take precedence over maintaining water supply/characteristics that will ensure constant ecosystem preservation
• I believe energy producers should pursue investments in energy technologies that reduce energy production's water use
• I believe energy producers are adequately investing in technologies that reduce the water use of energy production
• I believe energy producers should pursue investment in energy production technologies that use little water even if that increases the cost of energy to consumers
• I believe stakeholders representing energy production have more influence in water resource management than stakeholders representing other industry interests
• I believe stakeholders representing energy production have more influence in water resource management than stakeholders representing environmental issues
• I believe energy actors should have less influence in water resource management decisions
• I believe thermoelectric power production is a major threat to sustainable water resource management
• I believe hydroelectric power production is a major threat to sustainable water resource management
• I believe federal policies guiding electric power production should account for water resource impacts
• I believe current state policies guiding electric power production in Georgia are made with attention to water resource impacts
• I believe state policies guiding electric power production should include water resource impacts
• I believe stakeholders representing energy production have more influence in water resource management decisions than any other stakeholder group
• I believe the water use of energy production should be more regulated
• I believe more research should be conducted on the water use of energy production
• I believe current water regulations for energy production are sufficient
• I believe there is enough water on the ACF to support all current demands
• I believe there is enough water in the ACF to support all projected demands over the next 25 years
• I believe the general public is educated on the water use of energy production
• I believe greater integration between energy planning and water resource management is needed
• I believe there are adequate penalties in place for energy production facilities that violate water use regulations
• I believe there should be stronger penalties in place for energy production facilities that violate water use regulations

Copy of Administered Survey (Continued)
• I believe there should be an established governing body dedicated strictly to ensuring the water use of energy production is in line with water resource management
• I believe adequate municipal water supply is the most important issue facing water resource management
• I believe cities do an adequate job of managing municipal water supply in accordance with state water resource management
• Cities should be actively trying to decrease their water consumption
• City managers are well informed on the water resource management strategies of the State
• City managers are actively engaged in State water policy decision-making
• Georgia cities have local support for water conservation or efficiency policies or programs
• The Georgia legislature supports city water conservation or efficiency policies or programs
• Georgia cities have adequate resources (staff/funding) to develop water conservation or efficiency programs
• Georgia residents expect city managers to be active in state and regional water policy issues
• City conservation or efficiency policies and programs can effectively reduce municipal water consumption
• City managers have the flexibility necessary to enact effective water efficiency or conservation policies and programs
• The city managers that are most involved in water resource management are
• The city managers that are most involved in water resource management are - Other (please specify)
• The city managers that should be most involved in water resource management are
• The city managers that should be most involved in water resource management are - Other (please specify)
o Federal or state preemption of local authority -
o Difficulty coordinating with other agencies -
o Lack of clarity in the law -
o Lack of state mandated actions, policies, or programs -
o Conflicting state mandates -
• Why did you want to be involved in water resource management for the ACF? - Open-Ended Response
• Do you believe the current stakeholder process has been successful? Why or why not? Please define successful. - Open-Ended Response
• What do you think that other states facing water resource management conflicts could learn from the ACF stakeholder process? - Open-Ended Response

5.13.4 Results of Administered Survey

The online survey was administered to all one-hundred and seventy-two, past and present members of the ACF Stakeholders. Unfortunately, do the political sensitivity of the topic, only 25 members initiated the survey and only 8 members completed the survey. As a result, the sample set was very small and there was not enough data to provide statistical significance. Therefore, instead of providing a full analysis of the results, I offer a summary of the two sections of the survey that received the greatest response.

While the results of the survey administered to the ACFS is by no means conclusive, it is relevant to note that of the 25 completed surveys, the top three barriers that the ACFS members ranked as barriers to largest barriers to successful water resource management on the ACF, were:

- Poor Cooperation between State Leaders
- Lack of coordination between local, state, and federal decision makers, and
- Lack of consistency in legal rulings regarding water rights

Table 5-2 Results of ACF Stakeholder Survey on Barriers to Water Resource Management

Attribute	Total	Score
Poor cooperation between state leaders	11	21
Lack of coordination between local, state, and federal decision makers	11	20.36
Lack of consistency in legal rulings regarding water rights	8	19.75
The need to insure adequate water supply for agricultural use	7	18
The rules for water use allocation are not fair to all users	7	16.86
Historical legal constraints related to the riparian legal system	7	15.57
Maintaining environmental standards	8	15.38
Lack of technical knowledge supporting decision making	8	15.38

Table 5-2 (Continued)		
Lack of clear rules or boundaries for water users	9	15.33
State and Federal decision-makers respect for local knowledge	6	15.17
Unmetered surface water consumption	8	14.88
The need to insure adequate water supply for Georgia cities	7	14.86
Uncertainty about future water demand	7	14.86
The rules governing water resources do not match the demands on the water users	7	14.86
The need to insure adequate water for recreation	5	13.4
Lack of transparency in the decision-making process	8	13.38
The complexity and/or costliness of the decision-making process	6	13.33
Inability for those impacted by changes to water resource management to participate in the decision-making process	7	13.29
The need to insure adequate water supply for energy production	5	12.8
The need to insure adequate water conditions for fishing	7	12.57
The need adequate water for recreation	5	11.8
Uncertainty about future water supply under different climate scenarios	8	11.13
Lack of public participation in resource management decisions	5	10

Table 5-2 (Continued)		
Lack of penalties for breaking water use rules	7	8.71
Lack of involvement from municipalities	6	5.5

Additionally, survey respondents noted that the lack of a regional governing authority, and the continual reliance on the courts as major barriers. Combined these results suggest that there are large structural barriers, underscoring the 'rules-in-use' regarding water rights that are inhibiting successful collaboration. Interestingly, the survey respondents did not list a lack of penalties for breaking water use rules as a major barrier. This suggests that penalties are less important in collaboration as consistency in the law structuring use. Possible most surprising was the survey respondents listing that '*the need to insure adequate water supply for agricultural use'* was more inhibiting than the '*need to insure adequate supplies for Georgia cities.'* This runs counter to what most summaries on the source of water conflict on the ACF would report.

In regards to what is needed for successful water resource management on the ACF, survey respondents ranked *accurate scientific information, clearly defined water rights, and coordination between local, state,* and *federal management entities* as the major attributes necessary.

Table 5-3 Results of ACF Stakeholder Survey on Institutions Necessary to Successful Water Resource Management

Attribute	Total Count	Score
Accurate scientific analysis on physical restrictions	9	16.56
Clearly defined water rights	9	16.33
Coordination between local, state, and federal management entities	9	16.33
The inclusion of multiple and diverse stakeholder input	8	15.5

Clearly defined rules of use	9	14.89
Preservation of ecological habitats	8	13.63
Collection of data on water use	7	13.43
Monitoring of water use	8	13.38
Clear understanding of the costs and benefits of different allocation plans	8	12.38
Ability for all levels of stakeholders to influence policy decisions	8	12.38
Flexibility in the decision-making process	8	11.88
Insurance of adequate supply for agricultural production	7	11.14
The costs and benefits of water use are allocated equitably among users	7	10.71
Penalties for not complying with management decisions	7	9.86
Incorporation of local knowledge to management decisions	7	9.71
Insurance of adequate supply for recreational use	6	9.67
Insurance of adequate supply for energy production	6	9.5
Insurance of adequate supply for city water supply	6	9
Insurance of adequate water conditions for fishing industry	7	8.86
Recognition of the importance of local knowledge into the decision-making process	6	7.83
Penalties are reflective of the severity of the offense	6	7

Again, penalties are not a major concern for members of the ACFS. Most surprising is that the ACFS members ranked '*recognition of the importance of local knowledge into the decision-making process'* as the second least important aspect for successful management. This runs counter to what the literature states are the benefits of grassroots actors and potentially the benefits of including the ACFS in the governance process. This also suggests that while the ACFS recognize the importance of including a diversity of stakeholders in the governance process, ultimately the most important foundation is accurate scientific information. This, however, is not that surprising given that largely the purpose of the ACFS is to develop and disseminate that scientific knowledge.

CHAPTER 6. EXPLORING THE URBAN WATER-ENERGY-CLIMATE NEXUS AND OPPORTUNITIES FOR NICHE INNOVATIONS IN WATER RESOURCE MANAGEMENT

6.1 Introduction

Throughout this dissertation, I have examined the multiple facets related to the sustainable transition of energy and water systems. In each chapter I looked at the water systems and energy systems separately. In this chapter I begin the necessary evaluation of examining sustainable transitions through a nexus view. As explored in all previous chapters, the management of water and energy systems is directly linked to sustainable development because they incorporate different technological, technical, sociopolitical, geographical, and institutional dimensions. While the engineering and policy literatures are increasingly recognizing such linkages, often studies have been fragmented in their focus - isolating systems and their dynamics to their functional articulation or by trying to assess their individual response to landscape level pressures, such as climate change and demographic changes (Gasmelseid, 2012).

However, the complexity experienced in understanding the context of water and energy systems cannot be conceptualized through such partial views, but instead a holistic view must be taken. Separating water and energy policies as well as the stakeholders and technological solutions designed to combat against issues of resource constraints, economic development, and climate change is unlikely to address the development issues at the scale and pace needed (Perri, 2005). Rather, innovations that cut across both water and energy resource constraints are necessary, along with the qualitative institutional reform that will facilitate growth.

The energy and water systems in the United States are two separate, established regimes, each with their own institutional, economic, regulatory, and behavioral dynamics. Each have created a lock-in that makes it difficult for niche technological and governance innovations to transition (see chapters 2,4, and 5). And while the two regimes hold different attributes, technological innovations in each of them significantly affect the sustainability of the entire environmental system. However, despite the growing recognition throughout the policy and engineering literature our water, energy, and climate systems are fundamentally interwoven, there has been little research conducted to facilitate the role of niche technologies beyond their primary functional scope.

To accomplish this, a wider integrated approach is essential for identifying innovative transition pathways to sustainability. Such an approach will require a new paradigm orientation to enable mainstreamed transition towards more nexus-focused development pathways and will inevitably involve the destabilization of incumbent regimes and the emergence of new regimes involving novel configurations of technologies, actors, behaviors and rules (Geels, 2014).

Movement towards more holistic approaches to water and energy management will also require an expansion on the functional purpose of the niche innovations from solving a single system problem to solving a nexus of problems. However, despite the growing emphasis on improving the integration of water and energy systems by focusing on efficiency, involvement of cross-system stakeholders, and of improved resource planning practices (Gasmelseid, 2011), little has been done to understand sustainable transitions by the expanded purpose of niche energy and water technologies. The niche technologies that have been examined as pathways to sustainable transition, continue to be deployed as single purpose technologies (Helpman, 1998). [23] This approach of articulating niche technologies as only functionally relevant to one system, creates a path-dependency of isolation between the two systems and limits the potential for niche technological adoption (Gasmelseid, 2012)

Such functional limiting of niche innovations is even reinforced by the dominant management framework aimed at facilitating sustainable transitions. For example, the Integrated Urban Water Management (IUWM), a water management and policy framework focused on the coordinated and efficient management of water supply systems, focuses only on technological innovations ability to improve water system efficiency (Wilkinson 2012). These technologies are referred to as low-impact development (LID) water techniques and include such innovations as green water infrastructure, grey-water reuse, wastewater recycling, decentralized wastewater treatment, and repair and replacement of leaking water and sewer pipes (Garrison et al. 2009; Griffiths-Sattenspiel and Wilson 2009; University of California Berkeley (UCB) and University of California Los Angeles (UCLA) 2011). And while recently the literature has paid attention to the energy impacts of shifts in water use as well as how LIDs can contribute to decrease energy use (Malinowski et al., 2015; Allen et al. 2010; Government Accountability Office (GAO) 2011; USEPA 2013a, b), very little attention has been paid to how LID technologies may be strategically deployed to serve as tools for both energy and water systems.

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[23] Single purpose technologies are ones that have wide range of use across the economy but lack the characteristic of having many different uses. Helpman, E. (1998). *General purpose technologies and economic growth*. MIT press.

Considering that the vast majority of population growth is occurring in urban areas, in a time of increasing climatic change, cities become an excellent analytical space to understand how innovative policies and practices can be deployed to meet these changing conditions. The urban energy-water-climate nexus is an innovation in the policy framework for localities that recognizes the deep sociotechnical interdependence between these two systems within the current urban framework and the impacts of climate change that will shape governing policy accordingly (Yang, 2014). While investigations into how water and energy regimes must adapt to better account for their interlinked behavior have been extensively investigated across geographic regions (Cooley, 2011; Zhou, 2013; Dodder, 2011; Stillwell, 2015), there is a gap in the literature in regards to urban settings.

Yet, the challenges to urbanization also pose opportunities for niche innovation development, paradigm shifts in resource planning, and the institutional dimensions of sustainable transitions; there are opportunities in urban areas to develop and test the innovative policies, technologies, and behaviors needed to sustainably meet the expanding needs of society (Dodman, 2009).

Also, given the interlinked sociotechnical nature and associated trade-offs between water and energy consumption and production, it is important to contextualize research to evaluate specific opportunities and limitations within the appropriate scale. The urban water-energy nexus is location specific (Perrone et al. 2011). Differences in socioeconomic and political dynamics can create city-specific challenges and opportunities in water-energy management (Yang and Goodrich 2014) and climate change impacts. From a technical and economic perspective, regional differences influence the embodied energy, the GHG emissions, and energy costs of water (Mo et al. 2014) and regional differences greatly alter the embodied water and GHG emissions of energy production (Stillwell, 2012). From a political perspective, different legal and regulatory institutions, at different scales, not only shape the function and flexibility of energy and water systems but the opportunities for niche innovation adoption (See Chapters 2,3 and 5). Therefore, detailed understanding of the water-energy-climate nexus and how to deploy technologies to meet cross-system challenges of sustainable transition in an urban analysis is needed.

From a nexus perspective, better understandings are needed on the interdependencies and feedbacks between both systems. With improved information on the potential for niche technologies to serve as tools in the cross-system sustainable transition, it may be that policy makers and city planners can expand the scope and deployment of niche innovations. It also may be that with increased understanding of the expanded benefits of certain niche technologies, adoption will diffuse beyond the system niche and improve the pace of sustainable transition across systems. However, in order for policy makers to broaden their technological purview, and engage in an innovative nexus policy platform, more information is needed on the interactions between the water, energy, and climate in the urban setting as well as detailed analysis testing the potential technological and policy opportunities for a sustainable transition.

In this final chapter, I move beyond examining active subsystems and process within the energy and water subsystem to explore the potential for a qualitative shift in the management of energy and water systems and the continued approach of isolating the function of niche technologies. In this chapter, I return to the city and adopt a Water-Energy-Climate Nexus approach and access how niche innovations can support cross-system sustainable transitions.

6.2 Research Questions

In order to understand the potential for niche technologies to serve as cross-system solutions for sustainable transition, detailed analytics are necessary to facilitate improved policy. The research in this chapter seeks to answer four primary questions.

RQ1. What are the interactions between electricity use, water use, and emissions, in the city?

RQ2. Can niche energy innovations serve as tools for cross-system sustainable transition?

RQ3. What implications does this analysis hold for a nexus policy approach to sustainable transition?

To answer these three questions, I develop a tailored water-energy-climate nexus evaluation tool and apply it to a case study in Atlanta, GA. I evaluate two popular niche technologies from the energy and water system literature - distributed solar photovoltaics (DGPV) and rainwater harvesting (RWH) - and compare how the expanded use of each technology contributes to reductions in water use, reduce carbon emissions, reduce resource expenditures, and alleviates local water resource management concerns. I use these metrics to assess which technology produces the greatest amount of cross-system benefits. The primary purpose of this chapter is to lay the groundwork regarding the understanding of nexus interactions in the urban space and to contribute to the research on the urban water-energy nexus platform by providing detailed, geographically specific analysis on the direct and indirect relationships between energy use, water use, and climate. Our hope is that policymakers and researchers will build on the analysis provided in this study to further evaluate how to best strategically deploy niche technologies for cross-system sustainability gains and develop support better policies to foster adoption. To that end, I am interested in whether niche technologies that have largely been viewed as primarily energy purpose technologies are being undervalued, and if examined for their impact across systems could be given greater support. While RWH has consistently been framed as an innovative tool for sustainable transition of the water system, to my knowledge, no one has explored the potential for DGPV as a tool for meeting urban water transition challenges. Furthermore, despite growing recognition that nationally DGPV is a tool for reducing water-use stress in the power sector (NREL, 2016), to my knowledge this has not been explored at the city scale.

For my evaluation, I develop the Georgia Policy Analysis Tool (GPAT) and apply it to analysis of Atlanta, GA - a city at the center of a long-standing water resource management challenge (See Chapter 5). I analyze the impacts of a hypothetical deployment of RWH cisterns and DGPV on 2% of all new commercial and residential constructions in Fulton County. I adapt the model to scale to Atlanta's water supply system and to Georgia Power's electricity network. From my results, I explore what the implications may mean for innovations in urban water-energy-climate policy. This research provides policy makers with a better understanding of the connections between water and energy production, consumption, and management and seeks to expand the scope of technologies and pathways for water resource management and sustainable growth within the context of urban development and climate change.

6.3 Literature Review

Analysis on the urban water-energy-climate nexus aims to reveal the water-energy interactions within the context of urban development and climate changes. The past two decades have seen an increase in the research on the urban water-energy-climate nexus, driven in large part by an exploration on how current systems will adapt in response to increasing urbanization and climate pressures (C.A Scott, 2010). Understanding the connection between water use and energy use in urban areas and the connection between urban and regional impacts is becoming more critical as the demand increases (Cohen et al. 2004; Garrison et al. 2009; Griffiths-Sattenspiel and Wilson 2009; Sovacool and Sovacool 2009; Wilkinson 2012). Overwhelmingly this research has been focused in Australia (Kenway et al., 2011; Kenway et al., 2008; Marsh, 2008, Sharma et al., 2008a, Lundie et al., 2004, Kenway et al., 2008 and Fagan et al., 2010) with growing research in Asia (Rothausen and Conway, 2011; Fang, 2016; Y Gu, 2016) and South Africa (Landu and Brent, 2006, Friedrich et al., 2007 and Buckley et al., 2011).

Much of the literature in this space focuses on how the current silos of centralized resource delivery infrastructure (i.e energy and water delivery) are inefficient and in need of fundamental programmatic, institutional, and technological changes. With regard to urban water supply, the transition research has continually recognized that the vast majority of existing centralized conventional urban water systems are inefficient; likewise, are conventional centralized technologies for wastewater. With the increasing landscape pressures such as the changing environment of rapid urbanization, population growth, and environmental stressors from climate change, the incumbent water system regime is being stressed (Sharma et al., 2010).

Often the debate over technological innovation focuses on whether urban areas should continue the incumbent approach of expansion and maintenance of centralized systems that use conventional technologies for urban water supply or if there are more efficient, and economical means of meeting a growing water demand. And if the later, what institutional arrangements are necessary to facilitate a transition (Sovacool, 2015; Herring, 2010).

Within this growing discussion, Integrated Urban Water Management (IUWM) has become the leading paradigm for sustainable urban water resource management. IUWM considers water supply, wastewater treatment and disposal as an integrated system (Mitchell, 2006) and seeks to manage the entire centralized system holistically. Often this centers on the coordinated and efficient management of storm water, potable water, and wastewater-infrastructure systems within the urban water cycle with the solutions predominantly focused on supply-side approaches and technology shifts to alleviate water stress (Wilkinson 2012). However, the lack of existing infrastructure in some parts of the world and extreme scarcity in others, together with the compounding threat of climate change, increasing recognition of the tradeoffs between water and energy, and increasing demand for resources pose new challenges to the concept of Integrated Urban Water Management (IUWM). Simply put, is incrementally improving the efficiency of the incumbent system enough or is there a need to frame all urban decisions within a nexus platform?

While not in direct contrast to IUWM but often seen as an alternative or subordinate approach to IUWM, is the focus on the greater adoption of innovative decentralized low-impact development (LID) techniques including green water infrastructure, grey-water reuse, wastewater recycling, decentralized wastewater treatment, and repair and replacement of leaking water and sewer pipes (Garrison et al. 2009; Griffiths-Sattenspiel and Wilson 2009; University of California Berkeley and University of California Los Angeles, 2011) to solve water resources challenges as opposed to perfecting the centralized system (Cook et al., 2009). From a sociotechnical perspective, these technologies and the switch to a centralized resource management system represent niche innovations against the incumbent, centralized approach to water supply. Interestingly enough, much of the research on decentralized water resources has been conducted explicitly with the goal of ensuring that these new measures also contribute to climate change mitigation by reducing energy use and greenhouse gas emissions (Nair, 2014). The research has been deliberate in diagraming the relationship between water supply and energy use in water delivery and wastewater (Plappally and Lienhard, 2012; Stillwell, 2010; Yang, 2013).

Yet there are still many knowledge gaps including various aspects of energy intensity, regional impacts, and environmental impacts (Sharma et al., 2010). The studies that do provide the different aspects and impacts of decentralized urban water and wastewater technologies have been largely conducted in a piece meal fashion and do not account for how urban management decisions can have broader sectoral as well as geographic impacts (Venkatesh and Brattebo, 2011). There are a few notable exceptions. American Rivers et al. (2012) estimated that groundwater recharge from green infrastructure could save the City of Los Angeles over $23 million in energy costs each year. Garrison et al. (2009) estimated that the use of LIDs[24] in the urbanized areas of southern California and portions of the San Francisco Bay area could result in

[24] Examples of decentralized LID water technologies include: bioretention, grey-water reuse, rainwater harvesting cisterns, constructed wetland, grassed swales, green roofs, infiltration basins and trench, porous pavement, sand filter, and vegetated filter strips.

electricity savings up to approximately 1.2 billion kWh per year. Malinowski and Stillwell (2015) come the closest to conducting a nexus analysis that explores how urban resource management decisions can have regional impacts by including consumer-level energy savings and estimating that nationally, up to 3.8 billion kWh and $270 M could be potentially saved annually by replacing landscape irrigation and other outdoor water uses through rainwater harvesting alone.

However, despite the recognition of the co-benefit of LIDs, the scope of research on LIDs utilized to meet water resource challenges has been limited to decentralized water technologies, as such there is little research on the impact of the use of decentralized energy within the urban water-energy-climate nexus and how decentralized energy technologies may be used as tools to solve cross-system sustainability challenges. Under a water-energy nexus framework, future energy pathways would be contingent on water resource availability and in context of other competing resource needs (Webber, 2015). Following this thinking, there has been recognition that the use of renewable energy technologies is critical in any improved future water supply scenario (Yates, 2015) and the recognition that distributed energy resources, specifically DGPV, can be used to reduce water resource stress. Most recently NREL included the potential water savings from achieving National Sunshot initiative goals. NREL estimates that if Sunshot goals are met, the U.S could see a 4% reduction in power-sector water withdrawals and 9% reduction in water consumption through 2050 (NREL, 2016).

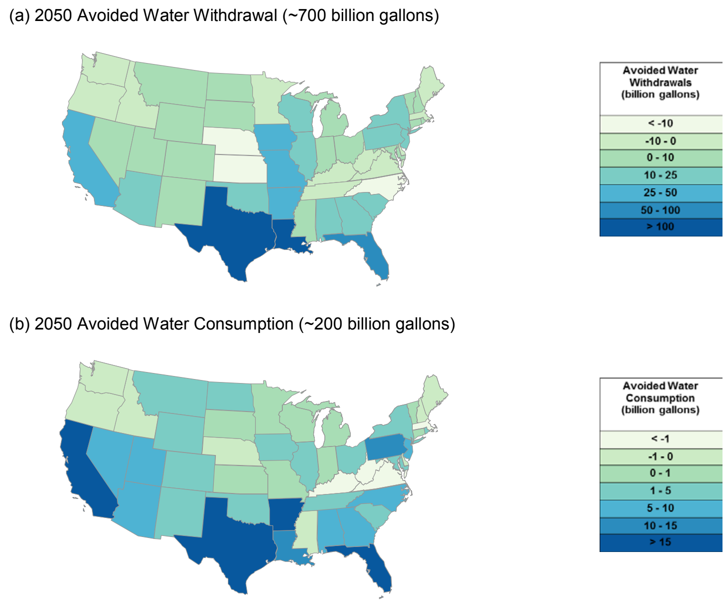

Figure 6-1-NREL's estimates of changes in water withdrawals (top) and water consumption (bottom) if SunShot goals are reached (NREL, 2016).

The ability of DGPV to reduce water withdrawals and consumption offers economic and environmental benefits, especially in regions where water is scarce or strained by competing demands. By reducing electric-sector water use, solar energy reduces the vulnerability of electricity supply to the availability or temperature of water, potentially avoiding electric-sector reliability events and/or the effects of reduced thermal plant efficiencies — concerns that might otherwise grow as the climate changes (DOE 2013). Moreover, increased DGPV can free up water for other purposes, including agricultural, industrial, or municipal use.

Unfortunately, despite recognition of the benefits that DGPV poses for water resource management, empirical studies on how DGPV can contribute to water resource management goals is a major gap within the nexus literature, even more so in an urban nexus platform. Very few have examined the role of distributed energy resources (DERs) or DGPV within a full nexus view, and those that have done have predominantly focused on DERs as means to powering decentralized water supply technologies (Zhang, 2013; Gold, 2015; Kjellsson, 2015). This gap in the literature makes it difficult for city planners, policy makers, and regulators to explore innovative cross-system policies that develop and employ cross-system innovation to meet sustainability goals.

6.4 Background on the Water and Energy Systems in Atlanta Georgia

Metro Atlanta straddles the headwaters of six river basins while relying on Lake Lanier, an impoundment on the Chattahoochee River, for more than two-thirds of its water supply (North Georgia Metropolitan Water Planning District, 2009). However, the Chattahoochee River watershed is among the smallest watersheds in the nation that provides the primary water supply source for a large metropolitan area. Lake Lanier's watershed covers a roughly 1,000 square miles and provides drinking water for nearly 5.5 million people.

As detailed in Chapter 5, for decades Atlanta has been at the center of a Tri-state water war — a conflict that is inherently a water-energy-climate nexus concern. Since 1990, Georgia, Alabama, and Florida have been engaged in a legal battle, over the use of water in the Apalachicola-Chattahoochee-Flint (ACF) River Basin and the Alabama-Coosa-Tallapoosa River Basin (ACT). At the heart of the conflict is the U.S. Army Corps of Engineers (Corps) operation of Lake Lanier's Buford Dam and whether or not the dam (that was primarily created for hydropower generation and flood control) could be used to supply water to Atlanta — which the Corps had been allowing without any evaluation and without any Congressional authorization.

Over the course of the Tri-State water wars, Atlanta's population has increased threefold, and the growth is expected to continue. At the same time, Georgia has experienced severe droughts, particularly in 2007, which exacerbated the on-going inter-state legal disputes over water rights and use. According to NOAA (2015) these droughts are expected to increase as the Southeast experiences hotter and dryer temperatures as a result of climate change.

Largely promoted by the ensuing legal battles, and to a lesser extent the growing recognition of resource constraints, in 2001 Georgia created the Comprehensive State-wide Water Management Plan. In concert with the State plan, the Metropolitan North Georgia Water Planning District was created, including 15 counties as well as 91 municipalities partially or fully within these counties. With the adoption of the Georgia State-wide Water Management Plan, the Metro Water District became one of eleven regional water-planning councils in the state. Within the Metropolitan North Georgia Water Planning District, the City of Atlanta was also responsible for creating a management plan that would both contribute to the North Georgia Metropolitan agenda as well as the greater Statewide objectives including water supply and conservation, wastewater management, and watershed protection.

With a planning horizon of 2030, the Metro District Board approved the first water plans in 2003. This was also the same year negotiations among Georgia, Alabama and Florida over the Apalachicola-Chattahoochee-Flint (ACF) Basin collapsed. While the original plan included a robust list of conservation measures many were later repealed in 2009, including a pledge to achieve 20% water savings by 2030. The target was replaced with a goal of 13% water savings by 2035. The plan also assumed that Lake Lanier withdrawals and the operation of Buford Dam would continue as they had over the past three decades.

In 2012, the city of Atlanta began drafting new water resource management measures. While there have been no explicit conservation goals put forward yet, objectives included:

1.) minimizing water use to generate electricity;
2.) quantifying water conservation/energy savings relationship;
3.) integrate water and energy practices; and
4.) maximize supply and end-use of water systems.

"The ultimate goal of water conservation is not to prevent water use, but to maximize efficiency and the benefit from each gallon used (North Georgia Metropolitan Water Supply and Water Conservation Management Plan, 2012)."

Despite the emphasis on better management and conservation, and the need to assess how shifts in Atlanta's water resource management may impact greater regional goals, there has been little headway in understanding how Atlanta policies can contribute to greater water use management goals in Georgia. In part this may be because to date, state leaders have been largely reluctant to impose any mandates on local governments or businesses, choosing to rely primarily on voluntary measures, with few associated metrics or benchmarks to track progress. However, according to Hart (2011) "perhaps the biggest impediment to achieving meaningful and measurable water savings through conservation is a misplaced focus. Instead of concentrating primarily on readily-available, cost-effective conservation measures. Georgia's leaders have chosen to focus largely on expensive, highly-engineered solutions such as new reservoirs and interbasin transfers, i.e., moving water from other river basins, to supply metro Atlanta. These “solutions not only send the wrong message as far as any commitment to conservation goes, but also undermine negotiations. Any future withdrawals out of the ACF River system are unlikely to be condoned by our downstream neighbors, at least until we maximize our water supply options through increased conservation efforts and existing water supply sources, including Lake Lanier (Hart, 2011, pg. 13).”

This may be the reason why despite recent analysis on the benefits of LIDs in Atlanta (Jeong, et al, 2016) as a means to achieve conservation efforts — there is little policy support for their use. For example, in many ways, RWH (a leading LID) just recently became legal in Atlanta. In 2009, Georgia’s State plumbing code — Georgia Amendments to the 2006 international plumbing code, Appendix I, “Rainwater Recycling systems” — allowed rainwater to be collected, treated and used indoors for toilet and urinal flushing, and as cooling tower make-up water. However, it wasn’t until 2011 that the city of Atlanta amended the plumbing codes, adopted the City of Atlanta Potable Rainwater Harvesting Ordinance (2011), and developed a permitting system for RWH, legitimizing their use. Before 2011, while it wasn’t illegal to install RWH systems, there was no permitting system that allowed their operation, leaving it up to local officials to decide whether or not to allow a potable rainwater system.

Of course, legal ambiguity around the deployment of decentralized resources is not unique to Atlanta. Legal barriers regarding the classification and use of water have prohibited the investment in RWH throughout the country (Golin et al, 2015). Many U.S. cities have no legal distinction between grey and black water, rendering domestic capture efforts technically illegal. Until recently, in many western states, water law stated all precipitation belonged to existing water-rights owners, and rain needed to flow to join its rightful water drainage. Other states have limited RWH use based on concerns over water-quality standards.

However, regulation is only one barrier in the greater adoption of RWH — cost is the other. Nationally, the average cost of water is less that 1 cent per gallon with an average residential water bill of around $85 (Circle of Blue, 2015). In comparison, the average cost of a residential RWH system is $5,250, which will supply between 50-70% of a residential water use, if local regulations allow RWH to be used for potable supply (Ecovarian, 2014). Comparatively, this makes the investment in RWH seem economically unjustified in the short run, with a payback period over eight years. With absolutely no government incentive to reduce the cost, it is not surprising that RWH is still not widely deployed.

Given Atlanta's lack of policy support for RWH, a traditional LID, it is not surprising that there has been no conversation on how non-traditional LIDs may be a tool for meeting water resource challenges. However, the energy sector represents a significant portion of statewide water demand in Georgia and as such has been at the center of the state's legal battles and water management concerns. With increased climate variability, increasing temperatures, increased drought, and increasing demand for electricity and water resources — water shortages might put the state of Georgia in a position where it is choosing between drinking water and energy. As with many regions in the U.S, water scarcity is more likely to occur in the summer and coincide with peak electricity demand. The compounding stress can exacerbate system vulnerability

(Field et al, 2014). Given that the electricity sector is such a major consumer of water resources and is highly sensitive to resource constraints, it is rational to look towards the electricity sector for innovative solutions.

While currently, water levels are sufficient to generate peaking power in Georgia, in low water years, once-through plants have experienced issues with thermal discharge. For example, in September 2007 Southern Company took one of the generators at Joseph M. Farley offline for maintenance. The overburdened ACF gave the utility little choice: flows past the Farley plant dropped below 2,000 cfs in October, and by late November had reached a low of 1,048 cfs (Carter et al. 2008). A study by the Union of Concerned Scientists recently studied the impacts of energy generation on the ACT in Georgia and concluded that:

"If current power generation and climate trends continue, the Coosa River will exceed a 90° threshold for thermal pollution 18 days a year from 2040 to 2049, which would significantly impact the health of the river. Basin wide, the annual average stream flow in the ACT is expected to fall 24% below the historical average for the same time period." (UCS, 2013, pg. 135)

In 2015 Georgia's thermoelectric power sector withdrew an average of 2,737 million gallons per day with about 187 million gallons per day consumed. Almost all of the water withdrawals associated with thermoelectric power generation in Georgia are from surface water sources. Coal-fired power plants, older (steam electric) gas-fired plants, nuclear power plants, and modern combined cycle gas plants are all dependent on water for steam processing, and primarily cooling. Older power plants, constructed prior to 1972, which use a once-through system where the water is discharged back into the water source. Newer power plants do not discharge water, but use cooling towers to evaporate the water. During 2005, Georgia's facilities with once-through cooling were responsible for about 88 percent of the thermoelectric sector's water withdrawals.

Georgia Power Company (GPC) has come under scrutiny over the past decade for its water use and potential exacerbation of the drought in Georgia. In 2008, the Governor's Office of Planning and Budget showed that the capacity of existing facilities and those planned through the year 2017 will not meet future statewide power generation needs through the planning horizon of 2050. One pathway to decreasing water use in the energy sector is to transition away from traditional thermoelectric generation and towards non-hydro, renewable energy. In Georgia, the primary, non-hydro renewable energy technology is solar photovoltaics. Overwhelmingly, the majority of solar in Georgia is in the form of large, utility-scale installations. There is very little DGPV in the state.

In large part, this is a result of the policy landscape. In terms of DGPV, there are a few programs in place to encourage adoption and there is no renewable portfolio standard in place for the state. And while Georgia Power operates two solar incentive programs in the state, overwhelmingly, the majority of projects developed under these programs were ground-mounted small solar farms in South Georgia. As of May 2016, there were 133 solar electric installations, with a capacity of 5 MW and an annual production of 6,973 MWhs in Fulton County (the main county for City of Atlanta).

However, the ability to pursue greater DGPV in Atlanta may be expanding. Recently, Georgia legalized the use of third party financing for DGPV. On May 12, 2015, Georgia passed the Solar Power Free-Market Financing Act, establishing the legality of “solar energy procurement agreements” (SEPAs), known elsewhere in the country as “power purchase agreements” (PPAs) to finance the construction and operation of a solar electric generation system. A solar company can now finance the construction of solar panels for a home, business or institution in Georgia, including public schools, government buildings, colleges and universities, military bases, etc., and be repaid for the system through payment by the property owner for the electricity produced by the solar system.

To date, the use of DGPV in Georgia has generally been framed solely in terms of economic costs and benefits (i.e bill reductions), and to a lesser extent marketed as a tool for CO_2 emissions reductions. To the best of my knowledge, DGPV has never been framed as a water savings technology in Georgia. However, the deployment of DGPV has the benefits of both reducing CO_2 emissions and decreasing regional water use. Considering the scale of the Atlanta region, which in 2010 was the 9th most populated, 6th largest energy consuming, 4th largest CO_2 emitting region in the nation, and facing drought and water supply shortfalls, framing DGPV as a tool for reducing water consumption, as well as energy and emissions, could incentivize greater policy support for the City and the State (Cox, 2014)

When looking at the policy landscape for decentralized water and energy combined, while the DGPV landscape has greater policy support, both technologies are not being widely adopted. In part, this is a cost barrier to both technology adoptions. However, the DGPV market is far more established in Georgia when compared to the RWH market, and the passing of SEPA’s for DGPV may reduce additional market barriers. When all the cross-system benefits of deploying DGPV are accounted for, there may be greater incentives for local policy makers to develop supportive niche policies and promote adoption. Particularly given Atlanta's strategic position in a tri-state water war, positioning distributed energy as a tool for sustainable water management may further incentivize adoption.

6.5 Examining the Cross-System Sustainability Opportunities for decentralized infrastructure in Atlanta, GA under a Water-Energy-Climate Nexus platform.

The purpose of this paper is to lay the groundwork for utilizing a water-energy-climate-nexus framework in Atlanta, GA for evaluating the potential of niche technologies to meet cross-system sustainability goals. In doing so I holistically asses the benefits and costs of distributed water and energy resources, and explore the validity of utilizing distributed energy as a tool for reducing water resource constraints in Georgia. To that end, I compare the deployment of rooftop DGPV with RWH cisterns under a full nexus analysis. For our analysis, I develop and apply the GPAT model to analyze and compare a hypothetical deployment of RWH and DGPV cisterns on 2% of all new commercial and residential square footage in Atlanta, GA from 2013-2020. I analyze the deployment of each technology in a water-energy-nexus system and account for water, energy, CO_2, and air quality impacts. I model both technologies from 2015 through 2030, assuming that both technologies will be deployed in Fulton County. While these distributed technologies have been analyzed for life-cycle impacts, to our knowledge, no study has analyzed the localized, system-wide dynamics of RWH and DGPV, comparing supply and demand effects, climate impacts, and economic costs and benefits.

Since I am specifically interested in how both technologies compare in meeting water resource management concerns, providing both the direct and indirect water savings is critical. RWH water savings are determined by the productivity of RWH cisterns to meet non-potable demand for commercial and residential buildings for the average day of a specific month coupled with the reduced water required to cool Georgia Power Company power-plants used to meet electricity needs of water distribution. DGPV water savings are comprised of the hourly reductions in water withdrawals and water consumption required to cool Georgia Power Company power-plants used to meet Atlanta commercial and residential load requirements.

6.5.1 GPAT Model Description

In order to understand and evaluate the nexus tradeoffs in Atlanta, we developed and applied the GPAT Model. GPAT is an integrated systems-environmental-economic modeling tool designed specifically to understand the holistic costs, benefits, and tradeoffs of distributed supply options for energy and water. The GPAT model combines GIS land-use data, hourly load and consumption profiles, detailed information about solar insolation and precipitation rates, health and welfare benefits of reduced pollution created by the AP2 model (Muller, Mendelsohn, & Nordhaus, 2011), capital and maintenance costs, degradation rates, water supply and electricity rates, withdrawal and consumption rates of water for electricity generation (scaled to technology source) as well as energy use rates for water supply. The model was developed in partnership between Matt Cox and Caroline Golin to analyze existing and possible future policy scenarios in Atlanta, GA. Currently GPAT is calibrated to Georgia Power Company electricity generation profile and Atlanta's water supply system. Unlike existing policy modeling software, GPAT accounts for feed-back loops between water, energy, and climate impacts, builds hourly profiles (as opposed to annual projections), can be calibrated to any geographical scale, and provides both supply or demand metrics. For complete documentation see the Appendix.

In calibrating GPAT, a number of model specifications were required. To determine average hourly load profiles and generation characteristics for electric power production, information from GPC reports to the Federal Energy Regulatory Commission, Energy Information Administration, and Integrated Resource Planning documents. To determine the water-use of power production, average daily load profiles and supply characteristics were developed from the EIA, Union of Concerned Scientists EW3 database (UCS, 2012), and direct conversations with Georgia Power Company. To determine average hourly emissions profiles, we utilized information from EIA (EIA, 860) and EPA (APMD, 2015) databases. Table 6.1 provides the water use and emissions profiles for GPC generation resources. GPC is unique in that despite large generation resources, GPC purchases over a quarter of its power. The majority of GPC purchased power is from Alabama Power, which has a very different hourly generation profile then GPC. To determine the carbon and water use of purchased power, we applied the SERC average. This resulted in a withdrawal rate of 15,029 gallons/MWh and a consumption rate of 434 gallons/MWh.

Table 6-1-Water Use and Emissions Profiles for GPC

	Baseload	CO2 Emissions	CO2 rate (t/MWh)	SO2 Emissions	SO2 rate	Nox Emissions	NOx rate	Water Source	Withdrawal rate (gallons/MWh)	Consumption Rate (gallons/MWh)
Barnett Shoals	N	0	0	0	0	0	0	Oconee River	0.00	5,100.00
Bartletts Ferry	N	0	0	0	0	0	0	Oconee River	0.00	5,100.00
Bowen	Y	10,532,524	1.10422096	3118.548	0.00032695	4651.1165	0.00048762	Etowah River	1,005.00	687.00
Bowen CT	N	0	1	0.2805	0.00800514	0.2145	0.00612158	Etowah River	780.3267475	468.1960485
Burton	N	0	0	0	0	0	0	Tallulah	0	0
Edwin I Hatch	Y	0	0	0	0	0	0	Altamaha	1101	672
Estatoah	N	0	0	0	0	0	0	None	0	5510
Flint River	N	0	0	0	0	0	0	Flint River	0	5510
Goat Rock	N	0	0	0	0	0	0	Chattahochee	0	5510
Hammond	Y	1,745,622	1.23620883	978.3095	0.00069282	1917.191	0.00135771	Coosa River	36,350.00	250.00
Harllee Branch	Y	2,359,265	1.12705672	20984.2775	0.01002451	4810.6065	0.0022981	Lake Sinclair	36,350.00	250.00
Jack McDonough CC	Y	5,111,251	0.4292513	26	2.1836E-06	245.6495	2.063E-05	Chattahoochee River	6738.076186	1604.303854
Jack McDonough CT	N	0	0	0.147	0	0.1715	0	Chattahoochee River	6738.076186	1604.303854
Kraft CT	N	0	0	0	0	0	0	Savannah	35,000.00	240.00
Kraft ST	Y	515,345	0.82962919	1190.1375	0.00191595	920.1835	0.00148136	Savannah	36,350.00	250.00
Langdale	N	0	0	0	0	0	0	Chattahochee	0	5100
Lloyd Shoals	N	0	0	0	0	0	0	Ocmulgee River	253	198
Looper Bridge Road Solar Project	N		0		0		0	None	0	0
McIntosh	Y	87,181	0	691.6	0	257.5295	0	Savannah	36,350.00	250.00
McIntosh Combined Cycle	Y	3,105,802	0.4133875	15.642	2.082E-06	161.476	2.1493E-05	Savannah	2530	150
McIntosh	N	25,969	1.30709776	0.1265	6.3671E-06	16.0075	0.00080571	Savannah	36,350.00	250.00
McManus	N	0	1	0	0	0	0	Turtle River	0	0
McManus CT	N	0	1	20.094	0.04471414	10.085	0.02244163	Turtle River	35,000.00	240.00
McManus IC	N	0	1	0	0	0	0	Turtle River	36350	250
Mitchell (GA)	Y	3,588	0	39.1845	0	10.187	0	Flint River	36350	250
Mitchell CT	N	0	1		0	0	0	Flint River	0	0
Morgan Falls	N	0	0	0	0	0	0	Chattahochee	0	5100
Nacoochee	N	0	0	0	0	0	0	Tallulah	0	5100
North Highlands	N	0	0	0	0	0	0	Chattahoochee River	0	5100
Oliver Dam	N	0	0	0	0	0	0	Chattahoochee River	0	5100
Riverview	N	0	0	0	0	0	0	Chattahoochee River	0	5100
Robins	N	2,129	1.18786183	0.0265	1.4786E-05	1.5595	0.00087011	Ocmulgee	0	5100
Scherer	Y	5,535,247	1.19425867	42349.1615	0.00913705	14986.591	0.00323344	Ocmulgee	1005	687
Sinclair Dam	N	0	0	0	0	0	0	Oconee River	0	5100
Tallulah Falls	N	0	0	0	0	0	0	Tallulah	0	5100
Terrora	N	0	0	0	0	0	0	None	0	0
Tugalo	N	0	0	0	0	0	0	Tugalo	253	198
Vogtle	Y	0	0	0	0	0	0	Savannah	1101	672
Wallace Dam 1	N	0	0	0	0	0	0	Lake Sinclair	0	510
Wallace Dam 2	N	0	0	0	0	0	0	Lake Sinclair	0	510
Wansley	Y	5,291,958	2.03356276	2101.742	0.00080765	1668.4815	0.00064115	Chattahoochee River	0	0
Wansley CT	N	0	1	0.596		0.166	0	Chattahoochee River	1005	687
Wilson	N	0	1	7.7615	0.0110201	16.185	0.02298013	None	0	0
Wilson IC	N	0	1	0	0	0	0	None	0	0
Yates	Y	2,644,335	1.11776911	29789.8645	0.01259227	3764.5455	0.00159129	Chattahoochee River	1,005.00	687.00
Yonah	N	0	0	0	0	0	0	Tugalo	0	5100

To determine the public health and welfare benefits of reduced pollution (from reduced grid energy) GPAT utilizes the AP2 model (N. Z. Muller, Mendelsohn, & Nordhaus, 2011), which generates damage estimates for six pollutants at various emission heights for every county in the United States through a Gaussian plume and Monte Carlo simulation procedure. Using this information, along with data from the USEPA National Emissions Inventory, the Energy

Information Administration State Energy Data System, Georgia Power Annual Reports, and others, a pollution-damage estimate for baseload and peaking generation was created. Matching these values with the hourly load profiles as a percent of baseload and percent of peaking enabled a refined picture of pollution reduction benefits to be determined. AP2 does not include a value for carbon dioxide emissions; this is included by applying the social cost of carbon, as determined by the US Interagency Working Group on the Social Cost of Carbon (Interagency Working Group on Social Cost of Carbon, 2013).

Table 6-2-GPC's Characterized Emissions Damage from GPAT

BASELOAD GPC Characteristics	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	5654.0	5848.5	647.8	5031.6	556.5	168.1	36.68	
Tons Emitted	0	1910	38245	109907	548	3532	40275376	
Net Generation	0	61010000	61010000	61010000	61010000	61010000	61010000	
Tons/MWh	1.51472E-05	3.13062E-05	0.000626868	0.001801459	8.98973E-06	5.78883E-05	0.660143851	
Damage ($)/MWh	0.09	0.18	0.41	9.06	0.01	0.01	24.22	33.97
NON-BASELOAD GPC Characteristics	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	9,565.00	9,015.39	697.59	5,763.82	824.84	326.67	36.68	
Tons Emitted	0	0	0	0	0	0	0	
Net Generation	-	-	-	-	-	-	-	
Tons/MWh	7.4192E-07	8.26125E-07	0.003091196	1.99391E-05	3.68716E-07	1.00178E-06	0.024393035	
Damage ($)/MWh	0.01	0.01	2.16	0.11	0.00	0.00	0.89	3.18
Purchased GPC Characteristics*	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	6,436.17	6,481.85	657.76	5,178.08	610.16	199.79	36.68	
Tons/MWh	1.22661E-05	2.52102E-05	0.00	0.00	7.26553E-06	4.6511E-05	0.60	
Damage ($)/MWh	0.08	0.16	0.29	1.67	0.00	0.01	21.92	
								24.14

To calculate social benefits and costs, GPAT uses a framework that builds off previous work analyzing energy policy alternatives by researchers with Oak Ridge National Laboratory and Georgia Tech (see Brown, Cox, & Baer, 2013; Brown et al., 2011 for more description and applications). This framework incorporates the monetary benefits of saved energy, saved water, the public health and welfare value associated with reductions in pollution, and the costs of equipment and grid connectivity to determine overall net benefits (or costs) of a particular policy.

6.5.2 Determining Rooftop Capacity for RWH and DGPV

To determine potential grid water savings from RWH as well potential rooftop space for DGPV, I first estimated the rooftop capacity for residential and commercial buildings using GIS and census data and regression models (For complete description see the Appendix). To estimate future size of residential and commercial roofing areas, numerous logistic regression models were developed and tested based on actual size of residential and commercial building footprint GIS layer called LandBase Structure from Fulton County.

LandBase Structure Data from Fulton County represent the base ground-level outline, or footprint of buildings and other man-made structures in Fulton County, Georgia. The original data was produced by digitizing structures from 1988 aerial ortho-photography combined with updates from aerial ortho-photography from 1999 to 2009. As individual polygons of residential and commercial building footprints can be directly interpreted as roofing area, we calculated total size of building footprint polygons and summarized by census tracts, which becomes dependent variable in our regression models.

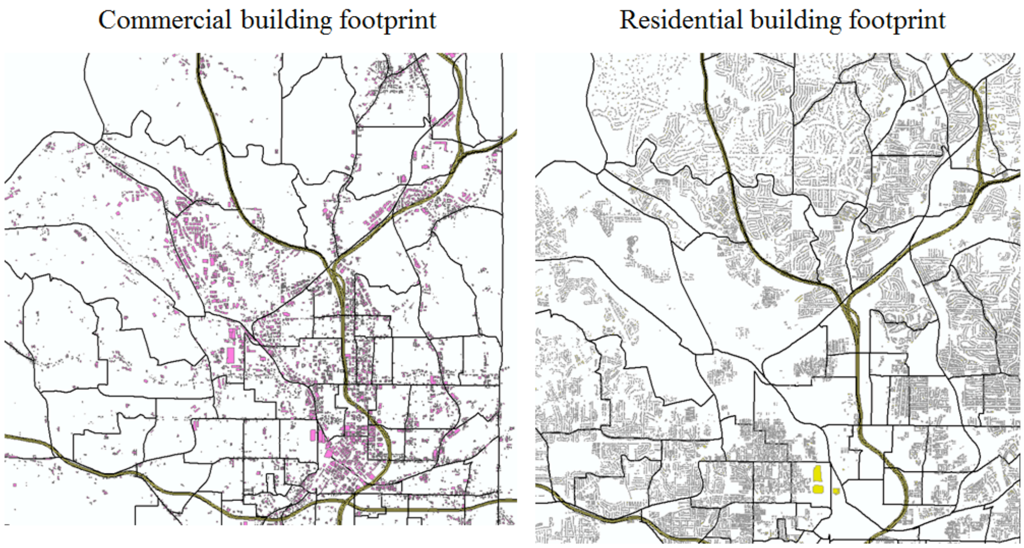

Figure 6-2-Residential and commercial building footprints in LandBase, Fulton County, GA

I conducted two series of regression models. One series for residential square footage and one for commercial square footage. The units of analysis in both models were census tract and the independent variables were:

- employment
- population
- average building square-footage (residential and commercial)
- population density
- commercial employment density
- total employment density
- distance to highways
- distance to city center
- distance to activity center
- tract size in the base year 2009.

The size of tract was included in the model as control variable because larger sizes of tracts are more likely to have more residential and commercial buildings. Numerous regression models were tested for a size of roofing area with different data scales (e.g. log transformation) in case the variables show a high level of skewness in its data distribution.

When various models were tested to estimate future the size of total commercial and residential roof area, population, employment, and population density were significant independent variables that explained 69% of the variation in the total size of commercial roof area and 78% of the variation in the total size of residential roof area. The t-statistic of these variables and the F-statistic test also show the overall model is statistically significant. Since the variables included log-transformations, the R-square value cannot be directly interpreted as the prediction power as taking exponentials to retransform the function might produce a bias (Stynes, Peterson, and Rosenthal 1986); however, the transformed model would still provide better results than raw-data model.

In the commercial model, population, population density, distance to city center, distance to highways, distance to activity centers and employment density in the model showed a positive impact, which indicates that as population and employment increase so too does the total size of roof. Interestingly, population density had a negative sign, meaning that higher density areas would have less total rooftop area if other conditions remain the same.

In the residential model only population and population density showed a positive impact, which indicates that as population increase so too does the total size of roof. Again, in the residential model, population density had a negative sign, meaning that higher density areas would have less total rooftop area if other conditions remain the same. This makes sense because typical single-family residential houses typically have larger rooftops than multi-family or high-density residential units, which typically reside in the region with a higher density than low-density suburban area. Based on the results, the total size of roofing areas in each tract was predicted using the following regression equations:

Equation 6.1 Total Roofing Areas for Commercial and Residential Buildings

$$Log(a_{c,k}) = 5.391 + 2.239 * \log(p_k) + 1.057 * \log(e_k) - 0.609 * d_k + .047 *$$

$$c_k - .150 * h_k - .170 * a_k$$

$$Log(a_{r,k}) = 5.37 + 2.94 * \log(p_k) - 0.738 * \log(d_k)$$

where:

$a_{c,k}$ = *square feet of commercial roofing area* $_k$

$a_{r,k}$ = *square feet of residential roofing area* $_k$

p_k = *population* $_k$

r_k = *residential count in* $_k$

e_k =*employment density* $_k$

d_k =*population density in tract* $_k$

h_k =*distance to highway in tract* $_k$

a_k =*distance to activity center in tract* $_k$

c_k =*distance to city center in tract* $_k$

Once I produced a significant model for estimating both commercial and residential rooftop in each land parcel, we projected future rooftop capacity through 2030 using census data projections on employment, population growth, and density. I assumed all other variables would remain constant. Table 6.3 shows the estimated roofing area in each projection year and the predicted new roofing area between 2010 and 2030. The result indicates that between 2013-2020, 442.8 million square feet of new roofing areas would be available by 2030.

Table 6-3-Total predicted roofing area through 2030 based on regression model for 13 counties

	2010	*2015*	*2020*	*2025*	*2030*
Total Predicted new roofing Area (million sqft)	87.2	89.1	92	88	86.5

In my analysis, we did not assume that all rooftop would be used for RWH or DGPV. Rather we assumed that 2% of all new rooftop from 2013-2020 would be available to have DGPV and RWH, translating to a total available rooftop space of 8.85 million square feet. through 2020.

6.5.3 Determining RWH Potential

Using GPAT we modeled the potential amount of non-potable water that could be supplied by rainwater harvesting from 2013-2020. I assumed collection efficiency of 0.50 (50%), which is in line with the current empirical literature (Stephen et al, 2013). I also assumed that only 75% of the rooftop would contribute to the rainwater cistern (Ecovarian, 2014). For determining daily rainfall, we averaged the daily precipitation rates for Fulton County from 2004-2014 using historical precipitation data from National Ocean and Atmospheric Administration (NOAA, 2014). I felt this was a good range of values as Fulton County experienced both wet and dry years during that time frame. Precipitation estimates were coupled with system efficiency estimates provided by industry reports to determine daily potential supply.

Equation 6.2 Rainwater Harvesting Supply

$RWH\ Supply = r{*}a{*}e{*}c$

where:

r= average daily rainfall

a= area of roof surface (sqft) * [144 square inches/sqft * 0.00433 gal/cubic inch]*

e= the collection efficiency of 0.50

c= rooftop contribution efficiency of .75

Next, I estimated the actual daily water demand for RWH supply to determine how much water would actually be utilized. This is a step that many studies do not include but is very important especially when considering system wide impacts and feedbacks. It is also important when determining cost because most RWH systems are sized and priced by gallon of demand. I assumed that RWH would only be used for non-potable indoor use and irrigation. I also assumed that rainwater could only be stored for 3 days. Since non-potable demand looks very different between commercial and residential buildings, and there is no formal data or reporting on water use in residential or commercial buildings in Atlanta, I combined 2003 estimates of per-capita residential water use and estimates of gallons per employee day provided by the Metropolitan North Georgia Water Planning District (see Table 6.4) with estimates on the water use in commercial buildings (Pacific Institute, 2010).

Table 6-4-Estimates on water use breakdown (Metropolitan North Georgia Water Planning District, 2003)

	Residential (g/c/d)	Commercial/ Industrial (g/e/d)	Multi-Family (g/c/d)	Residential Percentage of Total	Commercial Percentage of Total	Multi-Family Percentage of Total
Indoor Use	70	70	65	77%	72%	86%
Outdoor Use	21	27	11	23%	28%	14%
Total	91	97	76	100%	100%	100%

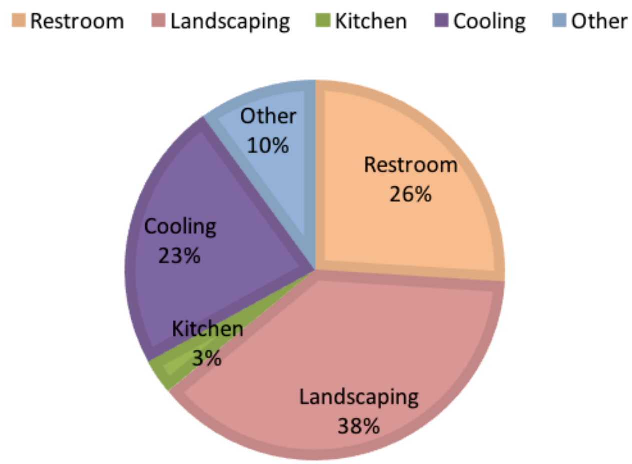

Figure 6-3-Water Use in Commercial Office Buildings (Pacific Institute, 2010)

Once the size of roofing area and amount of potential water saving through RWH was predicted, we estimated the net energy saved by using RWH systems as opposed to distributed public water supply. I utilized data provided by the Atlanta Watershed Department for two of the three, treatment plants — Hemphill and Chattahoochee — to determine a monthly average kWh/gallon of public water, which ranged between 0.0039 and 0.0028 kWh/gallon.[25]

[25] Energy use for the third plant that service Fulton County, Atlanta-Fulton County, which is shared, was not available.

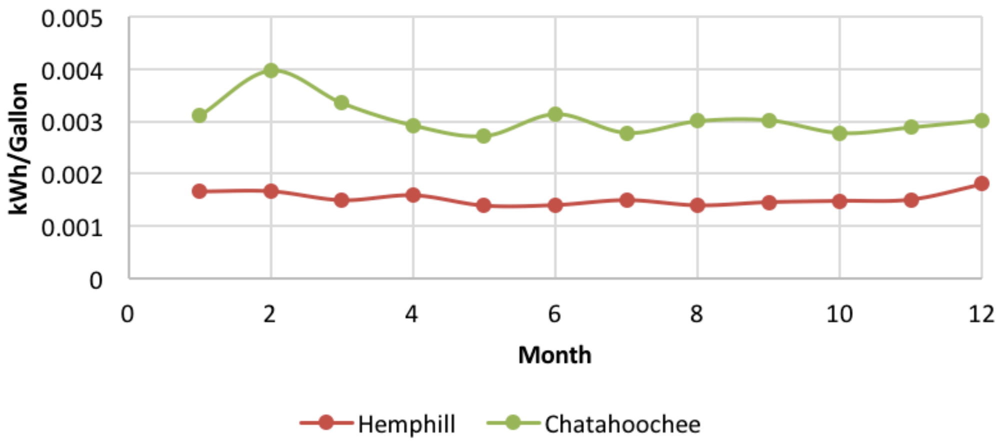

Figure 6-4-Monthly Energy Use of Water Treatment in Atlanta, 2014 (kWh/gallon)

In my estimation, I only included the energy needed to acquire and treat each gallon of water, as all water, potable or non-potable water, is treated in Atlanta. I did not include the costs of wastewater management. I also only attributed energy saved to water used within a three-day time period. Meaning that I did not attribute any energy saving to excess rainwater that is not utilized within three days. Grid water savings from decreased energy needed to distribute water were also calculated and integrated in to the daily, monthly, and annual water savings.

Table 6-5-Water and Energy Metrics for Water Distribution in Fulton County

Water Treatment Plant (WTP)	Plant Capacity (Dept. of Watershed) 10^3 m^3/day	Average Daily Flow (Dept. of Watershed) 10^3 m^3/day	Average Energy Use (Dept. Of Watershed) kWh/gallon	Cost of Energy ($/kWh)
Hemphill	517	152	.0035	.06

Chattahoochee	246	144	.00175	.06

The costs of RWH installations were priced based on square-footage and demand. From personal communications with a leading commercial-scale RWH developer (Ecovarian, 2014) in the Atlanta area, I estimated a $2.50 (commercial) and $3 (residential) per gallon of demand for the cost of a RWH rooftop cistern, pump, and initial permitting fees. Since I was only estimating non-potable use, we did not include the cost of a filtration system. The costs of a pump are included for residential units but not for commercial units. I assumed that commercial buildings will already be outfitted with pumps, making it difficult to determine how much extra pumping capacity (if any) would be needed with the use of RWH. Unlike the solar modules, we do not model a decrease in installation prices. I estimated that RWH performance would degrade at 0.05% per year (Ecovarian, 2014). Given that there is no public data on the number of installed RWH we baselined our starting participation per our conversations with industry specialist (Ecovarian, 2014).

Table 6-6-RWH metrics for Atlanta

	System Costs ($/gallon)	Gallons collected /sqft of roofspace	Annual Degradation (Ecovarian, 2014)	Ongoing Permitting Fees, Annually (City of Atlanta)	Square Feet in 2014	Total Participants (2013)	Cost of public water supply ($/gallon)
Residential	$3	16	.05%	$315.	600	3.6	$.01

Commercial	$2.50	18	.05%	$1637	7,000	9	$.01

6.5.4 Determining DGPV Potential

Based on conversation with local developers, we assumed that 50% of all residential rooftop space was suitable for DGPV and 40% of all commercial rooftop space was suitable for DGPV (Moreland, 2016). On average, solar panels in Atlanta will produce 15 watts per square foot of solar panel area (SolarPowerRocks, 2015).

Equation 6.3 DGPV Production

$$DGPV\ Supply\ = 9.2 * \ r_{c,r} \ {*a}$$

where:

a= area of roof surface

$r_{c,r}$*= rooftop suitability for r residential and c commercial*

To calculate the total hourly energy potential for DGPV I utilize the National Renewable Energy Laboratory's PV Watts calculator, which provides hourly production curves per kW of power, for solar that are scaled by local insolation rates.

The costs of solar installations were baselined to costs of new solar installations in Georgia as reported by the NREL's OpenPV database and Solar Power Rocks Reports (SolarPower Rocks, 2015). These costs have been declining, at a rate of roughly $0.80/W-installed/year over the last few years, but I assume this rate of decline will slow and estimate declining costs of 10% per year. Also included are parameters to capture the effects of improving technology and declining cell efficiencies over time. Solar cell efficiencies are anticipated to improve at 0.5% per year (IRENA, 2012), and performance is also modeled as degrading at 0.5% per year (Jordan and Kurtz, 2013). Commercial installations are modeled at a 25% price reduction from residential installed prices (SolarPower Rocks, 2015). Fees related to grid connectivity and permitting were determined from GPC documents regarding the costs of metering. Metering fees were estimated to be $48 and Interconnection Fees were estimated at $100.

Table 6-7-DGPV Metrics for Atlanta

	System Cost (2014, NREL OpenPV)	Rooftop Needed (sqft)/kW	Participants (2013)	Annual Degradation (Jordan and Kurts, 2012)	Square Feet in 2015	System Cost (2014, NREL OpenPV)	Metering Costs (GPC)	Average Retail Rate (c/kWh)
Residential	$2.88.	132	19	.5%	600	$2.88.	$148	12.2 c/kWHh
Commercial	$2.16	167	109	.5%	7,000	$2.16	$148	9.3 c/kWh

To determine the water saving potential from DGPV I used the average hourly electricity supply demand curves for residential and commercial buildings developed in GPAT, scaled to Georgia Power. The load profile curves where integrated with hourly emissions characteristics, scaled by fuel source and power plant, as well as water consumption and withdrawal rates. By using hourly electricity supply curves, I am able to determine how much local energy would actually be utilized and which power plants would be displaced by utilizing DGPV. This hourly calibration is an analysis that many studies do not explore but is very important especially when considering the emissions and water use impacts of investing in different technologies.

6.6 Results

I analyze the impacts of a hypothetical deployment of RWH cisterns and DGPV on 2% of all new commercial and residential constructions in Fulton County from 2013-2020. By 2020, the cumulative water savings from RWH, which includes the direct reductions in water demand as well as the water reductions associated with decreased power production for the distribution of water, totals to 3,294 Mgals. The cumulative water savings from DGPV totals 2,684 Mgals by 2020. Interestingly, while RWH directly contributes to substantial water reductions, when looking at RWH and DGPV combined, the greatest source of water reductions actually results not from on-site reductions (i.e from reduced water consumption in residential and commercial buildings) but from decreased water consumption and withdrawals from the power production as a result of DGPV and reduced energy needs to power the water distribution system. The fact that power plant water use is the major source water reductions is largely due to the generation profile of the power plants being used to meet load demands that are coincident with DGPV production as well as coincident with water distribution energy demands. In Atlanta, DGPV production as well as the production curves of water distribution is largely coincident with Georgia Power's hydropower, coal-fired power plants, and nuclear plants, which require significant water use.

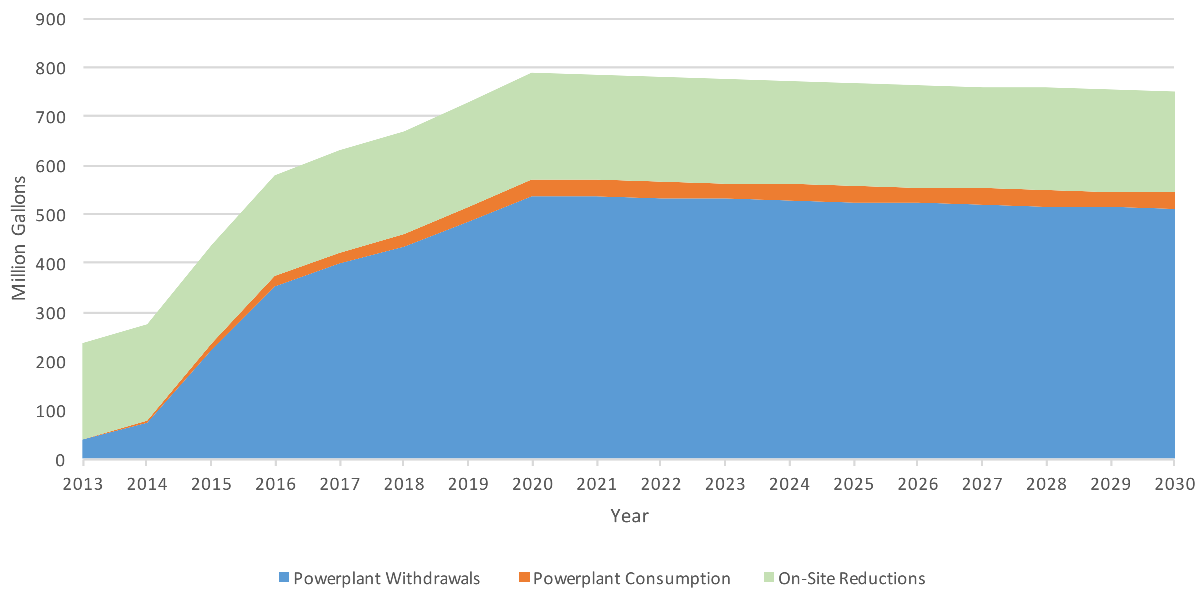

Figure 6-5-Breakdown of Water Savings by Source for RWH and DGPV

The cumulative reductions in grid energy reach 8.2 MWs of capacity. To put that amount of energy in perspective, that is enough energy to avoid building five to six peaker gas-powered plants. While the bulk of the energy savings is from DGPV, with total of 490,022 MWhs saved, RWH does result in a saving of over 2,641 MWhs from 2013-2020. As a result of these energy savings, we estimate the environmental impacts in the form of CO_2 and common pollutant emissions. These estimates are determined by the reduced grid energy during a specific hour during the average day of a specific month coupled with the reduced grid energy required to distribute water equal to the capacity that could be obtained on an average day. GPAT estimates the avoided common pollutants of NH_3, PM25, NO_x, SO_2, VOC, and PM10. By 2030, DGPV results in combined reduction of 1,018 metric tons of common pollutants and a total reduction of 297,451 tons of CO_2. RWH results in combined reduction of 5.64 metric tons of common pollutants and a total reduction of 1,592 metric tons of CO_2. The result of these reductions in common pollutants and CO_2 is improved air quality and according health savings. The quantity and value of avoided emissions grows with the expansion of RWH and DGPV. However, the addition of natural gas and nuclear to the grid also reduces the average damage per kWh, such that the average public health damages from power production fall 11% between 2014 and 2020.

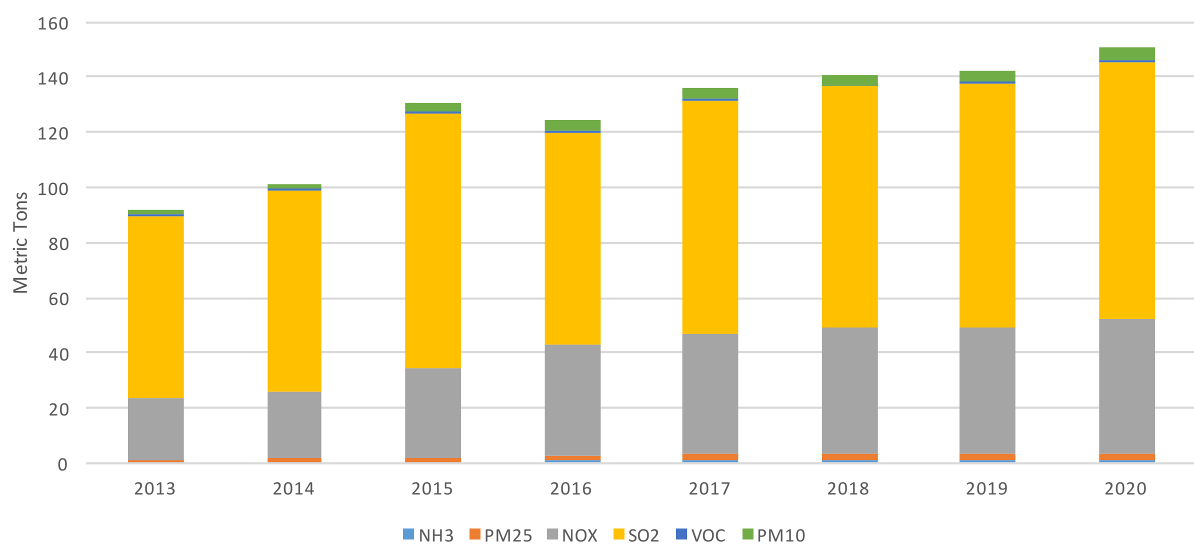

Figure 6-6.6-Emissions Savings from DGPV

The public health benefits to Atlanta that result from RWH and DGPV are still sizeable, with a cumulative value of $14.2 million (2014-$) through 2020. The overwhelming majority of these health savings can be attributed to DGPV, accounting for 90% of the public health benefits.

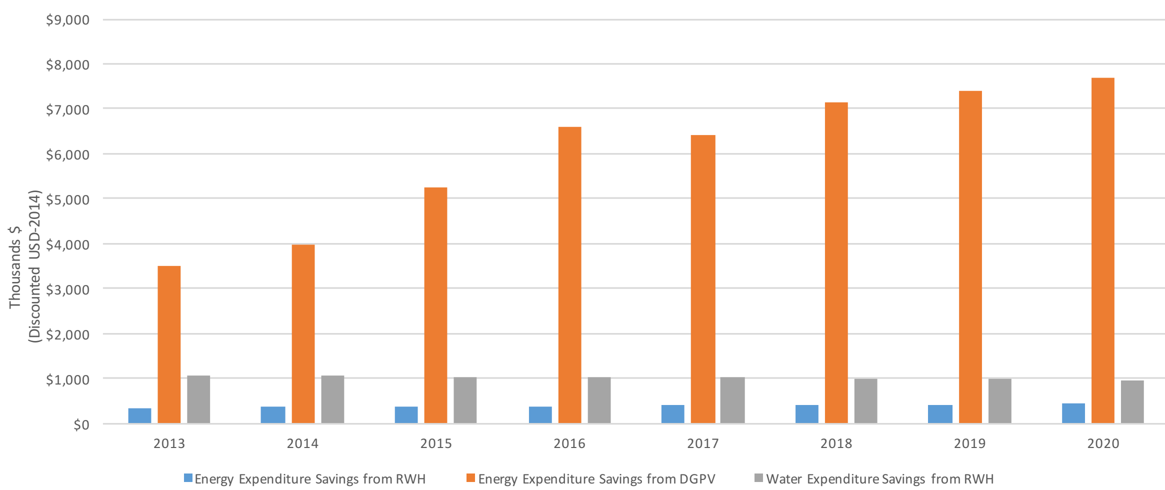

Figure 6-7-Expenditure Savings from RWH and DGPV (Discounted 2014-$)

6.7 Discussion

When examining the benefits of RWH and DGPV it is clear that both technologies result in environmental, social, and economic gains in addition to reductions in water use. What is interesting about this particular analysis is that despite DGPV being seen as primarily as a clean energy technology or a pathway for CO_2 reductions, it is surprisingly an extremely effective tool for reducing water use in power production, and thus freeing up water for alternative uses. In large part this is due to Georgia's specific generation profile, which tends to be extremely water intensive during the hours when DGPV is generating and displacing centralized production. When compared to RWH, DGPV is over 80% as effective at reducing water use. However, DGPV results in much greater gains in terms of CO_2 reductions and social benefits of improved air quality and decreased energy and water expenditures.

Table 6-8-Total Savings for RWH and DGPV (2013-2020)

Technology	Water Savings (million gallons)	Energy Savings (MWh)	Energy Expenditure Saving (million USD)	Water Expenditure Savings (million USD)	CO2 Savings (thousand tons)	Health Savings (million USD)
DGPV	2,700	490,000	$47	N/A	300	$ 12.78
RWH	3,300	26,400	$3.1	$8.8	1.6	$1.42

These results suggest that DG, particularly DGPV, may be a niche technology capable of solving cross-system sustainability goals and a tool that Atlanta can use to help contribute to regional water resource management goals and increased conservation. While this may not be true for every geography, certainly the generation profile of Georgia Power significantly shapes the water gains that can be provided by DGPV, it does provide tools and support for local policy makers to start exploring nexus solutions and assessing energy technologies as a means to achieve water conservation goals.

Of course, there are standing barriers to greater adoption of DGPV and RWH in Atlanta, including the lack of support within GPC and the economics of RWH. However, with the passing of HB57, there may be a potential for greater adoption if the market is able to deliver financing. The same cannot be said for RWH. Choosing between the two, this analysis suggests that DGPV may also be an economically efficient option for reducing water use in GA compared to RWH.

6.8 Conclusions and Policy Implications

The primary purpose of this analysis was to lay the groundwork necessary for taking a nexus view to sustainable transition, and assess niche innovations for their cross-system capabilities. To do this, I conducted a thorough examination of the interactions between energy use, water use, and emissions, as they relate to distributed resources in the urban space. I developed an integrated modeling tool, GPAT, designed to assess the direct and indirect relations between water, energy, and emissions in Atlanta, GA. I focused my analysis on the City of Atlanta, because it is a city that is at the center of a tri-state water war and is facing significant concerns in terms of water availability over the next decade and has yet to embrace niche technological innovations as a pathway to resource management. I used GPAT to understand how non-traditional innovations may be used to solve water resource management challenges. Specifically, I analyzed how DGPV may be used to alleviate local water resource concerns in cities with water stress. I compared the impacts of deploying RWH and DGPV, in their individual capacities to contribute to water use reductions as well as reduce CO_2 emissions, improve air quality, produce health cost savings, and expenditure savings. With this analysis, I questioned whether sufficient water, emissions, and economic savings could be realized from the implementation of DGPV to provide economic incentives that might encourage local policy makers to put greater support behind the niche technology, if recognized as a water savings tool, not only a clean energy tool.

My results show that DGPV produces significantly higher CO_2 reductions, expenditure savings, as well as health savings when compared to RWH. Additionally, DGPV results in comparable levels of water reductions, primarily from decreased water withdrawals from electric power production. Taken together, these results also suggest that policy makers need to reexamine the tools used to meet sustainability needs, a seek to examine a range of technological options for their cross-system capabilities. It also may be that by taking advantage of niche innovations, cross-system benefits may provide greater support, depending on the political climate. Given that Atlanta is at the center of a Tri-State water war, facing increasing pressures from climate change and urbanization, and the primary energy provider in Georgia has also been under scrutiny for its water profile, framing the use of DGPV as a means to reduce water use from power production, thereby alleviating stress on Atlanta's water consumption needs, as well as reduce CO_2 emissions and produce health benefits, may be an effective platform to pursue greater adoption of distributed resource technologies generally, and DGPV specifically.

However, incentivizing the cross-system benefits of DGPV is not without challenge and may take fundamental changes to the institutions which underpin the incumbent water system in Georgia. First, while DGPV reduces water consumption and withdrawals in power generation there is no direct financial benefit for DGPV owners for doing so. Currently in Georgia there is no price attached to water use for thermoelectric or nuclear power generation. This is not unique to Georgia but is a major market failure facing much of the developed world (Golin et al, 2015). Without creating a direct incentive or compensation for the water reductions provided by DGPV, it will be difficult to improve adoption rates to the scale necessary to really utilize DGPV as an effective tool for water resource management. Notwithstanding that there are additional policy barriers to the adoption of DGPV as an energy technology.

Additionally, policy-making between the water and energy systems remains largely disconnected in Atlanta, thus posing a problem for adopting a nexus viewpoint. Policymakers currently working to establish long-term water resource management strategies for Atlanta have yet to incorporate the influence of power generation in the State as a major variable. However, a first step of recognizing the potential of DERs may move policymakers towards a nexus viewpoint without the need to incorporate GPC into the management strategy, which may prove difficult. Moreover, under the current assessment framework for Atlanta's water resource management goals, evaluation is tied to intake from Lake Lanier. Water savings from DGPV, while providing benefits to the State and freeing up water resources for other interests, does not translate directly to reduced withdrawals from Lake Lanier. In order to recognize how Atlanta, through the use of DGPV, could contribute to state wide water resource management goals the City would need to develop a framework for accounting for all water use reductions- not just those from Lake Lanier.

Moving forward I hope to build on the groundwork analytics I have established in this research and explore niche innovations for their cross-system benefits. The research presented here is just one exploration into the opportunities for niche innovations if visualized through a nexus perspective. I hope the GPAT model and metrics provided in this research can provide tools for more research examining the best technological deployment strategies to meeting sustainability challenges. I also hope to explore expanding GPAT to other cities so as to understand how different technologies may contribute to a national transition and which investment patterns will speed the pace of transition and the ability to meet sustainability goals. Through building a strong resource of analytical and empirical results, policymakers will be able to expand their scope of tools to manage the growing development challenges of resource-constrained future.

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6.10 Appendix

6.10.1 Description of GPAT

The Georgia Policy Analysis Tool (GPAT) is a spreadsheet input-output model developed to understand policy implications regarding distributed energy and water policy options. It was designed, in partnership between Matt Cox, PhD and Caroline Golin, to provide relevant information regarding quantifiable streams of costs and benefits to different parties and to society overall. The model has the ability to provide information on:

- Hourly anticipated program energy and water savings to the grid
- Feedback between energy and water savings for shifts in supply technologies
- Public health and associated emissions benefits or costs

Model Description

GPAT is comprised of four main modules. It is also possible to use the outputs of these modules to inform and link to other models, like GT-DSM, which produce more detailed economic impact assessments for utilities and customers (such as rate and bill impacts, which can also be useful in energy policy dialogues).

The DS Inputs module is the main control module and the source of key inputs for the other modules. It requires a number of details about expected supply program characteristics and baselines in order to produce annual estimates of future performance.

The Generation module is calibrated to the major local water and energy utilities, detailing the generation profile of the utility as well as likely deployment class. Similar attributes for purchased power or water for the utility are added here as well, if available. Lastly, it determines hourly avoided generation based in part on DS Inputs module data.

The Emissions module determines the social costs of emissions based on the generation profile of the energy utility from the generation module, which assigns a dollar value to the public health consequences of the electricity generating technologies. This information is returned to the generation module prior to the final integration, projecting hour-by-hour differences.

Model Inputs

The following section details the inputs required for a specific module to run, starting with the DS Inputs module, followed by the Generation module and the Emissions module.

DS Inputs Module

The DS Inputs module requires a similar set of inputs, which can be expanded to any number of programs given user-supplied information. The inputs can also be divided between sectors (residential and commercial/industrial) to allow for more accurate representations of local conditions, if such data is available. What follows is a list of inputs necessary to successfully run the DS Input Module, along with a description of the input.

Avoided Electricity Generation or Water Production

$Y_i \frac{kWh}{KW}$

$Units: \frac{kWh}{KW}$

This is the expected average avoided generation of centrally produced electricity per unit-capacity installed as a result of the program. For example, an average residential photovoltaic (PV) system in Georgia is expected to produce roughly 1400 kWh/kW installed. This reduces the amount of electricity that has to be produced centrally by the amount that would be generated by PV system. Similar values can be determined for energy efficiency programs.

$Y_i \frac{gls}{sqft}$

$Units: \frac{gls}{sqft}$

This is the expected average avoided distribution of public water per square foot of installed RWH capacity as a result of the program. This reduces the amount of water that has to be distributed centrally by the amount that would be captured by the RWH system. Similar values can be determined for water efficiency programs.

Y_1 Total Capacity

Units: kW; mgallons

Programs are not always analyzed from the point of introduction. This is the total capacity of distributed resources that existed prior to Y_1. If the program is new to the area or is prospective and being analyzed prior to implementation using GPAT, this value should be set to 0.

Y_1 New Capacity

Units: kW; mgallons

This is the expected new capacity brought online in Y_1 as a result of the program.

Annual Efficiency Improvement

Units: %

This is the expected improvement in the efficiency of deployed distributed technologies that participate in the program. Cisterns, efficient technologies and renewable energy technologies may be anticipated to improve in energy performance over time. This value can be set to 0 if a user wants to produce a "no technology improvement" case, or believes that the technology will remain static over the modeling horizon.

Annual Degradation Rate

Units: %

This is the expected decline in performance of technologies deployed in the program. Many technologies experience a loss in operational efficiency over time, and this parameter allows for users to make such considerations.

Annual Growth Rate (capacity)

Units: %

This is the expected growth in capacity additions. Using this input simplifies calculations for users, but may not be applicable in all situations, as some programs have clearly defined capacity allocations and timelines. In such circumstances, this parameter should be set to 0 and the Defined Program Inputs (detailed below) should be used instead.

Installed Cost

Units: $/W; $/square foot

This is the total installed cost of a system. For solar pv the cost is based on a per-capacity basis. For RWH the cost is based on a per-square foot basis. The user must provide inputs for estimated installed costs through 2020. It is recommended that users take advantage reference materials from utilities, state and federal government, trade groups, industry specialists, and the academic literature in order to make such judgments.

Interconnection Fees

Units: $; $/gallon

This is the fee that the utility charges to connect a distributed system to the grid. For solar pv the fee is typically a flat fee in $. For efficiency measures, this may be $0, but is likely >$0 for renewable generating technologies. For RWH the fee in many areas is based on the size of the cistern and expected capture.

Meter Fees

Units: $

This is the fee that the utility charges to meter a distributed pv system on the grid. For efficiency measures, this may be $0, but is >$0 for renewable generating technologies.

Total Participants in Y_0

Units: Building Units

This is the number of building units (customers) that participated in the program prior to the model iteration start. For a new program, this value is 0.

Average Participant Growth Rate

Units: %

This is the percent of new building (customers) expected to request service annually; alternatively, this can be the annual percent change in demand.

Defined Program Capacity

Units: kW; total sqft

This is the amount of new capacity added to a program if program additions are dictated by program design. For example, a pv program may exist for 2 years and add 10,000 kW of capacity each year. Or a RWH program may add a percentage of existing or projected roof top area. In which case, using the Annual Growth Rate input would not capture the installation characteristics well. Using this optional approach will model such programs more accurately.

Defined Program Portions (residential and commercial/industrial)

Units: %

This is the amount of Defined Program Capacity to be allocated to the residential sector or the commercial/industrial sectors. Such details may be contained in program design documents and will enable more accurate modeling if included.

II. Centralized Electricity Generation and Centralized Water Production Module

The Centralized Electricity Generation Module combines information about hourly energy demand, estimations of hourly water demand based on daily water demand data, and the means of production used to meet that demand to estimate how centralized water and power production is deployed. The data required for the energy generation module are generally available for investor-owned utilities from the Energy Information Administration, Forms 923 and 860, SEC Filing 10-K, FERC Form 1, and the Environmental Protection Agency National Emissions Inventory.

However, information on hourly water demand and distribution is not readily available. Unless higher resolution is provided, we assume that water distribution follows a similar supply curve as energy and utilize daily supply estimates provided by local watershed management departments and fit total distribution to the hourly curve. In general, this section is the most data-intensive portion of GPAT.

Power Plants and Water Treatment Facilities Sub-Module

The Power Plants Sub-Module uses information about each power plant to construct a summary of plant operations by the major utility serving load in the geography of question. The capacity, capacity factor, water withdrawal, water consumption, and emission rates are necessary inputs, as is a determination of whether the plant is a baseload plant (plants that run most of the time to meet demand; they tend to be cheaper to operate but are also less capable of responding to quick changes in demand. Examples include coal and nuclear power plants, although others, like natural gas, can and are regularly used.). The units for each of these inputs are detailed below.

The Water Treatment Facilities Sub-Module uses information about each water treatment facility to construct a summary of plant operations by the major utility serving water demand in the geography of question. The capacity, operations, energy use, and average distance from water source and demand source are necessary inputs. The units for each of these inputs are detailed below.

There are also optional inputs that GPAT can use to produce some financial estimates for the energy utility regarding fuel and operations costs, which will be described following the required inputs.

Capacity for Powerplants

Units: MW

Capacity for Water Treatment Facilities:

Units: Mgals

Power plant Capacity Factor

Units: %

Water Withdrawal for Power plants:

Units Mgal/MW

Water Consumption for Power plants:

Units Mgal/MW

Energy Use for Water Treatment Facilities:

kWh/gal

Energy Use for Water Distribution:

kWh/mile

Total Energy Use for Water Supply:

kWh/gal

Emissions Rates Units:

Tons/MWh

Short tons of pollutants produced per MWh of electricity generated. Pollutants tracked, if possible, should include: SO_2, NO_x, $PM_{2.5}$, PM_{10}, VOCs, NH_3, and CO_2. If emissions rates cannot be discovered for each power plant by pollutant, the US EPA National Emissions Inventory can be matched to the US EPA eGrid data or EIA-923/860 to derive approximation values across all plants.

Electricity Baseload Determination

Units: N/A

A Yes/No determination of whether or not an electric generating unit is a baseload unit or not. In general, very large plants tend to be baseload, as do coal and nuclear plants. Plants with higher capacity factors are also likely being used to meet baseload demands. Optional Costs Inputs Units: $/MWh

These include the fuel cost per plant and the operations and maintenance cost per plant.

Purchased Power Sub-Module

The Purchased Power Sub-module calculates the average cost of power purchased by the utility based on financial filings. The preferred inputs are the price paid per MWh and the total purchased MWh by the utility, disaggregated by generator. However, an average price per purchased MWh can be used to produce estimates. These estimates are provided by GPC annual reports as well as in Southern Company's annual SEC filings.

Historical and Future Electricity Generation Capacity Sub-Module

The Historical and Future Capacity takes the existing capacity by fuel- type and based on existing characteristics, projects generation by fuel-type into the future, grouped as baseload or non-baseload generation. Future capacity is based on actual planned/under construction projects, and not based on any projections of unreported new developments or retirements. This module is capable of reporting power purchased from other providers that the utility buys energy from to meet demand, if this occurs, but the information related to purchased power is only reported by this sub-module. Characteristics related to purchased power are drawn from Load Curve – Centralized Generation sub-module. Inputs required for this sub-module are limited to the characterization of planned capacity additions (see below). If the user wishes to estimate the value of coal and natural gas fuel costs or savings, this module is also where the prices for those fuels should be input; it is recommended that appropriate EMM regional price trajectories from the EIA Annual Energy Outlook are used to inform utility fuel prices.

Fuel Type	2012 Capacity (MW)
Coal	9,714.70
Gas	3,382.80
Nuclear	1,933.30
Oil	1,310.90
Other Nonrenewable	1,662.30
Solar	0.7
Water	1,186.00
Total	19,190.70

Figure 6-8 2012 Capacity by Fuel Type, Georgia Power Company

Capacity in Y_X

Total utility-owned capacity by fuel-type by Year is required for this sub-module to operate. Users should input as many years of data as they can document to ensure the most accurate representation of utility operations.

Avoided Emissions and Distributed Generation Sub-Module

The Average Avoided Emissions and Distributed Generation Sub-module produces estimates of demand met on-site through renewable or efficiency technologies and RWH systems on the average day of each month.

Hourly Average Production

Units: Watts; Mgals

For solar pv, this is the watts of energy (or avoided energy, in the case of energy efficiency programs) produced by systems on-site per kW of system capacity, by hour, on average days. For RWH systems, this is the Mgals of water (or avoided water, in the case of water efficiency programs) produced by systems on-site per square foot of system capacity, by day, on average days.

Max Avoided Emissions, Water and Distributed Generation Sub-Module

The Max Avoided Emissions and Distributed Generation Sub-module produces estimates of demand met on-site through renewable or efficiency technologies and RWH systems on the maximum day of production for each month.

Hourly Average Production

Units: Watts; Mgals

For renewables this is the average watts of energy (or avoided energy, in the case of energy efficiency programs) produced by systems on-site per kW of system capacity, by hour, on highest production days.

For RWH this is the average Mgals of water (or avoided water, in the case of water efficiency programs) produced by systems on-site per square foot of system capacity, by day, on highest production days.

Water-Energy-Emissions Module

Emissions Damages Sub-module

The Emissions module derives monetary damages from pollutants from electricity generation from APEEP2 model outputs, used in a number of studies that estimate the societal damages from air pollution (N. Muller, Mendelsohn, & Nordhaus, 2011; National Research Council, 2010). Testing of the APEEP2 model by its authors has shown its marginal damage functions are essentially flat, meaning the marginal benefits will not decline as a new ton of pollutant is avoided (N. Z. Muller, 2011). APEEP2 calculates damages by pollutant (NH_3, SO_2, NO_x, $PM_{2.5}$, PM_{10}, and VOCs) by county for all counties in the United States. CO_2 emissions are also included in the Emissions Damages Sub-module, as determined by the US government (Interagency Working Group on Social Cost of Carbon, 2013).

Non-CO_2 Pollutant Damages

Unit: 2000-$/short ton

Expected marginal damage per short ton of pollutant (NH_3, SO_2, NO_x, $PM_{2.5}$, PM_{10}, and VOCs) by county at effective emission heights of 250-500m and >500m. Taken from A2 model outputs (N. Z. Muller, Mendelsohn, & Nordhaus, 2011).

Table 6-9 Point Sources for Power Plants in GPAT

	Point Sources: Effective Height 250 meters - 500 meters					
	NH3	PM25	NOX	SO2	VOC	PM10
MEAN MARGINAL DAMAGE (2009-$/Short Ton)	9565	9015.39	697.5	5763.8	824.8	326.6

Table 6-10 Marginal Damages utilized for GPC in GPAT provided by AP2(N. Z. Muller, Mendelsohn, & Nordhaus, 2011)

Marginal Damage (2009-$/Short Ton)	Point Sources: Effective Height > 500 meters							
	fips	NH3	PM25	NOX	SO2	VOC	PM10	Associated Power Plant
	13015	4601.57	5018.013	586.0334	4283.71	476.2572	142.2675	GA POWER CO: BOWEN
	13015	4601.57	5018.013	586.0334	4283.71	476.2572	142.2675	GA POWER CO: BOWEN
	13015	4403.45	4895.925	585.0523	4268.26	465.2671	137.985	GA POWER CO: BOWEN
	13015	4403.45	4895.925	585.0523	4268.26	465.2671	137.985	GA POWER CO: BOWEN
	13021	4022.1	4062.875	442.1276	3689.75	389.4484	116.475	ARKWRIGHT
	13021	4022.1	4062.875	442.1276	3689.75	389.4484	116.475	ARKWRIGHT
	13021	4022.1	4062.875	442.1276	3689.75	389.4484	116.475	ARKWRIGHT
	13021	4022.1	4062.875	442.1276	3689.75	389.4484	116.475	ARKWRIGHT
	13067	4616.23	4917.178	564.6949	4133.52	466.8566	141.9525	GA POWER CO: MCDONOUGH
	13067	4616.23	4917.178	564.6949	4133.52	466.8566	141.9525	GA POWER CO: MCDONOUGH
	13077	5804.43	5452.513	550.6616	4240.08	515.0447	159.2775	GA POWER CO: YATES
	13077	5804.43	5452.513	550.6616	4240.08	515.0447	159.2775	GA POWER CO: YATES
	13077	5804.43	5452.513	550.6616	4240.08	515.0447	159.2775	GA POWER CO: YATES
	13077	5532.17	5254.99	541.7682	4156.9	497.1948	153.96	GA POWER CO: YATES
	13077	5532.17	5254.99	541.7682	4156.9	497.1948	153.96	GA POWER CO: YATES
	13115	4736.06	5224.198	580.877	4312.05	494.8512	148.9725	GA POWER CO: HAMMOND
	13115	4736.06	5224.198	580.877	4312.05	494.8512	148.9725	GA POWER CO: HAMMOND
	13115	4736.06	5224.198	580.877	4312.05	494.8512	148.9725	GA POWER CO: HAMMOND
	13115	4409.62	4975.175	577.3749	4278.45	472.4189	140.565	GA POWER CO: HAMMOND
	13121	4619.84	4809.045	554.5198	4137.6	457.0839	138.675	Owens Corning Asphalt/Roofing
	13149	4723.54	4823.285	547.0672	4148.71	458.3542	138.585	GA POWER CO: WANSLEY
	13149	4723.54	4823.285	547.0672	4148.71	458.3542	138.585	GA POWER CO: WANSLEY
	13207	4000.36	4112.588	457.5761	3771.54	393.9459	117.7725	GA POWER CO: SCHERER
	13207	4000.36	4112.588	457.5761	3771.54	393.9459	117.7725	GA POWER CO: SCHERER
	13207	3971.38	4084.478	455.5263	3746.53	391.3829	117.2325	GA POWER CO: SCHERER
	13207	4003.46	4117.898	457.8063	3772.43	394.4259	117.9225	GA POWER CO: SCHERER
	13237	3935.32	4142.318	456.8117	3823.42	396.5567	119.6325	GA POWER CO: HARLLEE BRANCH
	13237	3935.32	4142.318	456.8117	3823.42	396.5567	119.6325	GA POWER CO: HARLLEE BRANCH
	13237	3903.27	4116.318	456.3656	3819.12	394.1973	118.9125	GA POWER CO: HARLLEE BRANCH
	13237	3903.27	4116.318	456.3656	3819.12	394.1973	118.9125	GA POWER CO: HARLLEE BRANCH

CO_2 Pollutant Damages

Unit: 2012-$/metric ton

Expected marginal damage per metric ton of CO_2 emitted as a result of power generation at any height. Taken from the US government's Social Cost of Carbon determination(EPA, 2016).

Water Usage Submodule

Powerplant Water Withdrawal by Fuel, Capacity, Capacity Factor, Cooling technology, and Baseload Determination

Unit: Mgallons/MWH

The Union of Concerned Scientists publishes the water withdrawal rates of power plants in Georgia in the EW3 database (UCS, 2012). The database provides the estimates for minimum and maximum withdrawal with the associated fuel source, capacity, capacity factor, and cooling technology. From this data set (in combination with our generation data) we were able to allocate a baseload determination for the system. We were also able to determine estimates for water withdrawal during peak and off-peak generation hours. We assumed that water withdrawal rates would be at their highest during peak summer months, and that lowest during a specific power-plant's lowest output.

<u>Powerplant Water Consumption by Fuel, Capacity, Capacity Factor, Cooling technology, and Baseload Determination</u>

<u>Unit: Mgallons/MWH</u>

The Union of Concerned Scientists published the water consumption rates of power plants in Georgia in the EW3 database. We followed the same methodology as water withdrawal calculations. For the few plants that were not reported we used literature estimates to determine the sum of the water consumption of plants that share similar characteristics. For example, a baseload, combined cycle, natural gas plant, that uses a cooling tower, has an average minimum water consumption of 198 gls/MWH and an average maximum of 300 gls/MWH.

Major calculated results in the Power Plant Sub-module are baseline year capacity, generation, generation-weighted capacity factor, and emission rates by fuel and baseload determination.

Table 6-11 Water and Emissions metrics of GPC power plants

	Baseload	CO2 Emissions	CO2 rate (t/MWh)	SO2 Emissions	SO2 rate	Nox Emissions	NOx rate	Water Source	Withdrawal rate (gallons/MWh)	Consumption Rate (gallons/MWh)
Barnett Shoals	N	0	0	0	0	0	0	Oconee River	0.00	5,100.00
Bartletts Ferry	N	0	0	0	0	0	0	Oconee River	0.00	5,100.00
Bowen	Y	10,532,524	1.10422096	3118.548	0.00032695	4651.1165	0.00048762	Etowah River	1,005.00	687.00
Bowen CT	N	0	1	0.2805	0.00800514	0.2145	0.00612158	Etowah River	780.3267475	468.1960485
Burton	N	0	0	0	0	0	0	Tallulah	0	0
Edwin I Hatch	Y	0	0	0	0	0	0	Altamaha	1101	672
Estatoah	N	0	0	0	0	0	0	None	0	5510
Flint River	N	0	0	0	0	0	0	Flint River	0	5510
Goat Rock	N	0	0	0	0	0	0	Chattahochee	0	5510
Hammond	Y	1,745,622	1.23620883	978.3095	0.00069282	1917.191	0.00135771	Coosa River	36,350.00	250.00
Harllee Branch	Y	2,359,265	1.12705672	20984.2775	0.01002451	4810.6065	0.0022981	Lake Sinclair	36,350.00	250.00
Jack McDonough CC	Y	5,111,251	0.4292513	26	2.1836E-06	245.6495	2.063E-05	Chattahoochee River	6738.076186	1604.303854
Jack McDonough CT	N	0	0	0.147	0	0.1715	0	Chattahoochee River	6738.076186	1604.303854
Kraft CT	N	0	0	0	0	0	0	Savannah	35,000.00	240.00
Kraft ST	Y	515,345	0.82962919	1190.1375	0.00191595	920.1835	0.00148136	Savannah	36,350.00	250.00
Langdale	N	0	0	0	0	0	0	Chattahochee	0	5100
Lloyd Shoals	N	0	0	0	0	0	0	Ocmulgee River	253	198
Looper Bridge Road Solar Project	N		0		0		0	None	0	0
McIntosh	Y	87,181	0	691.6	0	257.5295	0	Savannah	36,350.00	250.00
McIntosh Combined Cycle	Y	3,105,802	0.4133875	15.642	2.082E-06	161.476	2.1493E-05	Savannah	2530	150
McIntosh	N	25,969	1.30709776	0.1265	6.3671E-06	16.0075	0.00080571	Savannah	36,350.00	250.00
McManus	N	0	1	0	0	0	0	Turtle River	0	0
McManus CT	N	0	1	20.094	0.04471414	10.085	0.02244163	Turtle River	35,000.00	240.00
McManus IC	N	0	1	0	0	0	0	Turtle River	36350	250
Mitchell (GA)	Y	3,588	0	39.1845	0	10.187	0	Flint River	36350	250
Mitchell CT	N	0	1		0	0	0	Flint River	0	0
Morgan Falls	N	0	0	0	0	0	0	Chattahochee	0	5100
Nacoochee	N	0	0	0	0	0	0	Tallulah	0	5100
North Highlands	N	0	0	0	0	0	0	Chattahoochee River	0	5100
Oliver Dam	N	0	0	0	0	0	0	Chattahoochee River	0	5100
Riverview	N	0	0	0	0	0	0	Chattahoochee River	0	5100
Robins	N	2,129	1.18786183	0.0265	1.4786E-05	1.5595	0.00087011	Ocmulgee	0	5100
Scherer	Y	5,535,247	1.19425867	42349.1615	0.00913705	14986.591	0.00323344	Ocmulgee	1005	687
Sinclair Dam	N	0	0	0	0	0	0	Oconee River	0	5100
Tallulah Falls	N	0	0	0	0	0	0	Tallulah	0	5100
Terrora	N	0	0	0	0	0	0	None	0	0
Tugalo	N	0	0	0	0	0	0	Tugalo	253	198
Vogtle	Y	0	0	0	0	0	0	Savannah	1101	672
Wallace Dam 1	N	0	0	0	0	0	0	Lake Sinclair	0	510
Wallace Dam 2	N	0	0	0	0	0	0	Lake Sinclair	0	510
Wansley	Y	5,291,958	2.03356276	2101.742	0.00080765	1668.4815	0.00064115	Chattahoochee River	0	0
Wansley CT	N	0	1	0.596		0.166	0	Chattahoochee River	1005	687
Wilson	N	0	1	7.7615	0.0110201	16.185	0.02298013	None	0	0
Wilson IC	N	0	1	0	0	0	0	None	0	0
Yates	Y	2,644,335	1.11776911	29789.8645	0.01259227	3764.5455	0.00159129	Chattahoochee River	1,005.00	687.00
Yonah	N	0	0	0	0	0	0	Tugalo	0	5100

The coefficients presented in Table AV.4 were calculated from using emissions data and water use data with matched generation data from the US EPA eGrid data, EIA-923/860/823, and UCS EW3 database.

<u>Energy Use of Water Distribution Submodule</u>

<u>Unit: kWh/gallon</u>

This is the marginal energy used obtain and distribute water for daily public supply. This data should be provided by the local authority. If not national estimates can be used.

Calculations Module

The Calculations Module provides the calculations for the modules and sub-modules and are listed below. Some of the sub-modules that are a part of the GPAT model do not have inputs, rather taking endogenous outputs from other sub-modules for their routines. As a result, they were only mentioned in glancing in the inputs section, but will have a larger role in this section. The calculations here will be generalized, but may have sector-specific forms in actuality based on the input data and calibration of the model.

DS Inputs Module

From the inputs provided to the DS Inputs Module, a number of values are calculated forward as a % increase over existing characteristics. These equations generally follow the form of Equation E.1:

Equation 6.4 General Rate of Change

$X_t = X_{t-1} \times (1+\%Change)$

Calculations following this form include: annual capacity additions; new participants; kWh/kW and Mgal/sqft for installations from Year Y_t, where Y_t experience an increase in efficiency as technology improves, yet also a decrease in efficiency each year the systems are operational.

Total generation and capture (or generation and supply avoided, as the case may be) and Total participant outputs are calculated as the sum of efficiency-adjusted existing generation and new generation, or the sum of existing participants and new participants.

Other outputs from the DS Inputs Module are aggregations of information from other calculations, like total annual generation and total installation costs.

Generation Module

The different sub-modules of the Generation module calculate a number of outputs, many of which are intermediary outputs used to inform another sub-module. Eventually, the calculations result in the creation of two hourly demand profiles; one that would occur without the evaluated program, and one with the program.

Power Plant and Water Treatment Facility Sub-Module

Major calculated results in the Power Plant Sub-module are baseline year capacity, generation, generation-weighted capacity factor, and emission rates by fuel and baseload determination.

Powerplant Capacity by Fuel and Baseload Determination

This is the sum of the capacity of plants that share these characteristics; for example, there might be five baseload bituminous coal plants of 500MW capacity each, so the value calculated would 2500MW of baseload bituminous coal.

Generation by Fuel and Baseload Determination

Generation is calculated from capacity and capacity factor inputs for each plant by multiplying capacity, capacity factor, and hours-per-year values. These plant-specific generation values are then summed in similar fashion to capacity to produce baseload determination specific generation estimates by fuel.

% of Generation by Baseload Determination

This value is calculated as the sum of generation by fuel and baseload determination and dividing by all generation of that baseload determination.

Generation-Weighted Capacity Factor

Generation-weighted capacity factors are calculated to provide an estimate of the average capacity factor of the plants by generation-type, as shown in Equation E.2:

Equation 6.5 Generation-Weighted Capacity Factor

$CF_{F,B} = G_{F,B}/(8760 \text{ x } C_{F,B})$

where: $CF_{F,B}$ is the generation-weighted capacity factor by fuel and baseload determination;

$G_{F,B}$ is generation by fuel and baseload determination

$CF_{F,B}$ is capacity by fuel and baseload determination, and

8760 is the number of hours in a year.

The same value is calculated irrespective of fuel to produce a generation-weighted baseload capacity factor and a generation-weighted non-baseload capacity factor.

Water treatment plant Capacity

This is the sum of the capacity of the water treatment plants in the geographical region

Energy Use of Water treatment plant Capacity

This is the total energy used to treat water for daily public supply. This is based on the type of treatment and the total daily capacity of the plant. Energy use is calculated from multiplying capacity for each treatment plant, energy use per gallon of daily capacity (based on treatment technology), and days-per-year values. These plant-specific values are then summed to produce energy estimates by Mgal.

Energy Use of Water Distribution

This is the total energy used obtain and distribute water for daily public supply. This is based on the average distance of the treatment facility to water source, the total water distributed, and the average distance from the treatment facility to the end-demand source. Energy use is calculated by dividing the total daily supply by the sum of the total distance traveled in miles, and then multiplying by the average energy use for distribution based on water source (ground or surface).

$$\sum(\frac{S}{\sum D} * A)$$

where *S* is the total daily supply for each treatment facility, in Mgals and

D is Sum of the total distance traveled, in miles

A= the average energy use for distributing water based on water source, in kWh/Mgal

This metric is then multiplied by days-per-year values to produce annual estimates.

Generation-Weighted Emissions Rates

Generation-weighted emissions rates are calculated for the seven pollutants. Rates specific to the utility should be calculated when possible, however, utility-reported information doesn't always contain all seven pollutants. In general, it should be possible to get utility emissions data for CO_2, SO_2, and NO_X, while EPA National Emissions Inventory estimates for emissions by fuel-type may be needed for other pollutants. This calculation generally takes the form shown in Equation E.3:

Equation 6.6 Generation-Weighted Emissions Rates

$$PollutantRate_{F,B} = (G_{1F,B} \text{ x } PollutantRate_{G1} + G_{2F,B} \text{ x } PollutantRate_{G2} \dots G_{nF,B} \text{ x } PollutantRate_{Gn})/G_{F,B}$$

where $G_{1F,B}$ is the generation from plant 1, etc.

The resulting rate is tons of pollution/MWh by fuel and generation type.

Power plant Historical and Future Capacity Sub-Module

The Historical and Future Capacity Sub-module takes the generation characteristics produced by the Power Plant Sub-module and produces a number of outputs for future years based on planned capacity additions and retirements. It assumes that the capacity factor by fuel and baseload determination remains a constant over the modeling horizon. Inputs to this sub-module determine the capacity additions and retirements.

Using $CF_{F,B}$ and total capacity figures, $G_{F,B}$, % of Generation by Baseload Determination, and non-fuel specific generation-weighted capacity factors are calculated for each year that data is available; any year beyond the final inputs provided to the Historical and Future Capacity Sub-module are assumed to have the same characteristics as the final year of input data. Non fuel-specific generation-weighted capacity factors are important, as they are used to calculate the capacity that is ready for dispatch in any given hour, as shown below. Ready-for-Dispatch Capacity

Ready-for-dispatch capacity is determined by calculating the overall capacity by baseload determination and multiplying it by the generation-weighted capacity factor by baseload determination from the baseline year, as shown in Equation E.4:

Equation 6.7 Ready-for-Dispatch Capacity

$$DC_{B,Y} = \Sigma C_{B,Y} \text{ x } (\Sigma G_{B,0}/(\Sigma C_{B,0} \text{ x } 8760))$$

where: $DC_{B,Y}$ is the ready-for-dispatch capacity by baseload determination in year *y*

$\Sigma C_{B,Y}$ is the sum of capacity in the same baseload determination in year *y*

$\Sigma G_{B,0}$ is the sum of generation in the same baseload determination in year 0

$\Sigma C_{B,0}$ is the sum of capacity in the same baseload determination in year 0

Load Curve and Centralized Generation Sub-Module

The Load Curve and Centralized Generation Sub-module takes historical average hourly demand data by month.

For energy use this data is reported to FERC and makes a projection of hourly demand into the future. This is done by multiplying the hourly demand in the baseline year by the Annual Average Demand Growth Rate from the DS Inputs Module. It then apportions this demand into baseload, non-baseload, and if called for, purchased power. Ready for dispatch capacity is deployed first; based on its method of calculation, it is the equivalent of running those assets with 100% capacity factors, and thus should always be deployed. If demand drops below the sum of baseload and non-baseload ready-for- dispatch capacity, non-baseload capacity is taken offline. If demand exceeds the sum of baseload and non-baseload ready-for-dispatch capacity, power purchases are made until demand is met.

For creating an hourly water supply, data is limited. Currently GPAT uses the metric Gallons per Employee Day (GED) to estimate the use of potable and non-potable water for the commercial sector and the estimate of gallons per person (GPP) to estimate the demand of residential buildings. Both GED and GPP estimates are provided by USEPA, USGS, and local reports (if applicable). To determine number of employees and residents, GPAT uses the estimates based on census projections. If hourly water use data is not provided, GPAT matches the hourly load curve for water to the hourly load curve of energy.

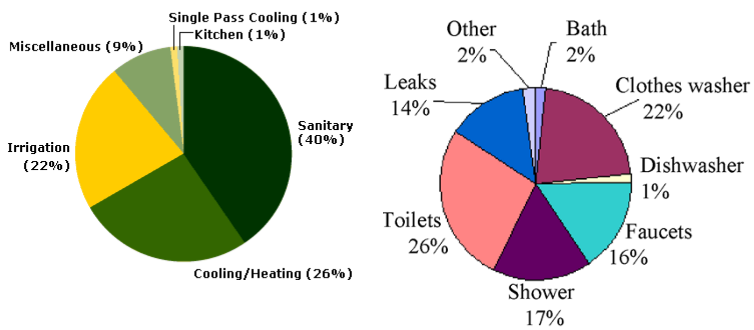

Figure 6-9 Estimated water use per employee (left) and per person in a household (right)

Average and Max Avoided Emissions and Distributed Generation Sub-Modules

For solar pv, the average production by a distributed system (residential or commercial/industrial) is calculated by the hourly power per rated capacity data input to the module, multiplied by the capacity of the average system, input to the DS Inputs Module. Average hourly generation by month from distributed resources is calculated in the Average Avoided Emissions and Distributed Generation Sub-module.

For RWH, the average production by a distributed system (residential or commercial/industrial) is calculated by the daily capacity data input to the module, multiplied by the capacity of the average system, input to the DS Inputs Module. Average hourly generation is determined from daily capacity. Then average hourly generation by month from distributed resources is calculated in the Average Avoided Emissions and Distributed Generation Sub-module.

For any given hour, the calculation of demand met by distributed resources resulting from the program is shown in Equation A.V.5:

Equation 6.7 Hourly Distributed Demand

$ADD_{h,m,y} = AP_{h,m,y}$ x Participants

where: ADD is the average distributed demand met in a specific hour, month, and year;

AP is the average production by a distributed system in a specific hour, month, and year;

Participants are the number of program participants from the DS Inputs

Module From these values, hourly, daily, monthly, and annual distributed generation/capture (or avoided centralized generation/supply) can be calculated. However, not every day will be an average day for all technologies. The Max Avoided Emissions and Distributed Generation Sub-module enables users to have 1 maximum day for each month included in the assessment of distributed generation (or avoided centralized generation). The calculations for producing outputs are the same, relying on different $AP_{h,m,y}$ inputs from users.

Final Generation Sub-Module

The outputs of the Load Curve and Centralized Generation Sub-module are combined with the outputs of the Average and Max Avoided Emissions and Distributed Generation Sub-modules to produce hourly projections of demand, and how that demand is met, whether by baseload, non-baseload, purchased power, or distributed pv for energy, and public supply or distributed RWH systems for water. As a general rule, demand met by distributed resources is used on-site and thus avoids the use of centralized, grid-provided water and power. This is calculated by giving each month one max day, with all others being average days, and producing a new hourly generation value. In determining the final generation picture, distributed generation and capture is subtracted from centralized generation and supply.

However, specifically with energy, there are multiple blocks of centralized power. Since non-baseload power contains peaking generation, typically the most expensive source of generation to the utility, distributed resources are subtracted from the non-baseload ready-to-dispatch capacity first. Should distributed resources exceed the capacity met by non-baseload capacity in a given hour, they would then reduce purchased power, followed finally by baseload generation. The result of this calculation is the generation supplied by non-distributed resources to the grid.

Emissions Module

The Emissions Module calculations combine a number of the Emissions Module inputs with the outputs from the Generation Modules to produce estimates of the effects of different approaches on total emissions and related social costs.

Emissions Damages Sub-Module

The Emissions Module takes the damages per ton inputs and converts it to damages per MWh by baseload generation type and for purchased power. Using the mean marginal damage per ton inputs to the module and the pollutant emissions rate (tons/MWh) from the Power Plants Sub-module, damage/MWh can be determined for the baseline year for baseload and non-baseload generation. Purchased power, since it may vary year-to-year, uses a generation profile that is taken from the Energy Information Administration's Annual Energy Outlook, referencing the generation profile and emissions from the appropriate Electric Market Module region.

Damages are reported in \$/MWh, and continue to be calculated annually for baseload, non-baseload, and purchased power generation, from the changes in generation mix determined in the Historical and Future Capacity Sub-module and the Power Plants Sub-module.

Table 6-12 Emissions Calculations for GPC

BASELOAD GPC Characteristics	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	5654.0	5848.5	647.8	5031.6	556.5	168.1	36.68	
Tons Emitted	0	1910	38245	109907	548	3532	40275376	
Net Generation	0	61010000	61010000	61010000	61010000	61010000	61010000	
Tons/MWh	1.51472E-05	3.13062E-05	0.000626868	0.001801459	8.98973E-06	5.78883E-05	0.660143851	
Damage ($)/MWh	0.09	0.18	0.41	9.06	0.01	0.01	24.22	33.97

NON-BASELOAD GPC Characteristics	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	9,565.00	9,015.39	697.59	5,763.82	824.84	326.67	36.68	
Tons Emitted	0	0	0	0	0	0	0	
Net Generation	-	-	-	-	-	-	-	
Tons/MWh	7.4192E-07	8.26125E-07	0.003091196	1.99391E-05	3.68716E-07	1.00178E-06	0.024393035	
Damage ($)/MWh	0.01	0.01	2.16	0.11	0.00	0.00	0.89	3.18

Purchased GPC Characteristics*	NH3	PM25	NOX	SO2	VOC	PM10	CO2	Sum Value
MEAN MARGINAL DAMAGE (2009-$/Ton)	6,436.17	6,481.85	657.76	5,178.08	610.16	199.79	36.68	
Tons/MWh	1.22661E-05	2.52102E-05	0.00	0.00	7.26553E-06	4.6511E-05	0.60	
Damage ($)/MWh	0.08	0.16	0.29	1.67	0.00	0.01	21.92	
								24.14

<u>Average and Max Avoided Emissions and DG Sub-Module</u>

The process for calculating avoided emissions benefits is the same for the Average and the Max Avoided Emissions and DG Sub-module.

Hourly production by baseload determination (baseload, non-baseload, purchased) from the Load Curve and Centralized Generation Sub-module is matched to emissions damages from the Emissions Damages Sub-module to produce the marginal damage per MWh from the grid. The percent of generation from each of the three baseload determinations is multiplied by the damage per MWh, and then all products are summed to produce the marginal damage per MWh. These values are calculated hourly for the average day in each month through the modeling horizon, as shown in Equation E.6:

Equation 6.8 Hourly Marginal Damage

$HMD = \Sigma\%G_{b,h,m,y} \times MD_b$

where: HMD is hourly marginal damage, in $/MWh

$\%G_{b,h,m,y}$ is the percent of all generation by baseload determination in a specific hour, month, and year

MD_b is the marginal damage ($/MWh) by baseload determination

The value of avoided emissions damages are calculated by taking total avoided centralized generation outputs from this module and multiplying by HMD. The result is the hourly emissions benefit from the modeled distributed resources program. These are then aggregated to daily, monthly, and annual output values.

6.10.2 Estimating volume of water from rainwater harvesting using GIS building footprint and regression models Sub-module

To estimate future size of residential and commercial roofing areas, numerous logistic regression models were developed and tested based on actual size of residential and commercial building footprint GIS layer called LandBase Structure from Fulton County. LandBase Structure Data from Fulton County represent the base ground-level outline, or footprint of buildings and other man-made structures in Fulton County, Georgia. The original data were produced by digitizing structures from 1988 aerial ortho-photography and updates were made from aerial ortho-photography from 1999 to 2009. As individual polygons of residential and commercial building footprints can be directly interpreted as roofing area, we calculated total size of building footprint polygons and summarized by census tracts, which becomes dependent variable in our regression models.

We conducted two regression models. One for residential square footage and one for commercial square footage. The units of analysis in both models were census tract and the independent variables were:

- employment
- population
- average building square-footage (residential and commercial)
- population density
- commercial employment density
- total employment density
- distance to highways
- distance to city center

- distance to activity center
- tract size in the base year 2009.

The size of tract was included in the model as control variable because larger sizes of tracts are more likely to have more residential and commercial buildings. Numerous regression models were tested for a size of roofing area with different data scales (e.g. log transformation) in case the variables show a high level of skewness in its data distribution.

Descriptive statistics and the bounds of variables for the regression model are as follows:

Table 6-13 Summary of Commercial Regressions

Variables	OBS.	Min.	Max.	Mean	Std. Dev.
SIZE.ROOF (SQFT)	198	241,971	23,422,075	3,900,304	2,888,309
POP2009 (PERSON)	166	424	36,788	5,778	4,125
Emp2009 (PERSON)	166	3	37746	3,298	5,560
POPDEN(PERSON/ACRE)	166	.15	64.34	6.45	6.41
TRACT SIZE (ACRE)	166	25.1	45,753	2,058	4,523

Table 6-13 (Continued)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.831[a]	.690	.670	.75913

a. Predictors: (Constant), DistToActvCtr_Mile, COMEMP_09, Tract_SQFT, COMsqft_per, AVGSzCOM, LNPOP_09, DistToHwyExits_Mile, LN_POPDEN09, LN_COMEmp_Dens, DistToAtlCtr_Mile

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	193.982	10	19.398	33.661	.000[b]
	Residual	87.017	151	.576		
	Total	280.999	161			

a. Dependent Variable: LN_CommericalSQFT

b. Predictors: (Constant), DistToActvCtr_Mile, COMEMP_09, Tract_SQFT, COMsqft_per, AVGSzCOM, LNPOP_09, DistToHwyExits_Mile, LN_POPDEN09, LN_COMEmp_Dens, DistToAtlCtr_Mile

Table 6.13 (Continued)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.391	.984		5.480	.000
	Tract_SQFT	-4.012E-010	.000	-.060	-.825	.411
	LNPOP_09	2.239	.299	.512	7.484	.000
	LN_COMEmp_Dens	1.057	.157	.527	6.747	.000
	COMEMP_09	-6.423E-006	.000	-.034	-.482	.631
	LN_POPDEN09	-.609	.133	-.355	-4.571	.000
	COMsqft_per	-.044	.620	-.005	-.070	.944
	AVGSzCOM	1.794E-005	.000	.078	1.331	.185
	DistToAtlCtr_Mile	.047	.017	.261	2.824	.005
	DistToHwyExits_Mile	-.150	.069	-.165	-2.155	.033
	DistToActvCtr_Mile	-.170	.070	-.174	-2.437	.016

a. Dependent Variable: LN_CommericalSQFT

Table 6.13 (Continued)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.884[a]	.782	.769	.58973

a. Predictors: (Constant), REScount_per, size09, Tract_SQFT, DistToActvCtr_Mile, LNPOP_09, DistToHwyExits_Mile, LN_POPDEN09, sf09, DistToAtlCtr_Mile

Table 6-14 Summary of Residential Regressions

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	194.238	9	21.582	62.056	.000[b]
	Residual	54.254	156	.348		
	Total	248.492	165			

a. Dependent Variable: LN_RESSQFT

b. Predictors: (Constant), REScount_per, size09, Tract_SQFT, DistToActvCtr_Mile, LNPOP_09, DistToHwyExits_Mile, LN_POPDEN09, sf09, DistToAtlCtr_Mile

Table 6-14 (Continued)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.371	.956		5.616	.000
	Tract_SQFT	-1.665E-009	.000	-.267	-4.291	.000
	LNPOP_09	2.948	.256	.736	11.505	.000
	LN_POPDEN09	-.738	.105	-.464	-7.054	.000
	DistToAtlCtr_Mile	.001	.015	.006	.066	.947
	DistToHwyExits_Mile	.067	.054	.079	1.237	.218
	DistToActvCtr_Mile	-.010	.052	-.011	-.184	.855
	size09	-.177	.109	-.071	-1.631	.105
	sf09	9.528E-005	.000	.112	1.599	.112
	REScount_per	.309	.177	.131	1.749	.082

a. Dependent Variable: LN_RESSQFT

The t-statistic of these variables and the F-statistic test show both models are statistically significant. Since the variables included log-transformations, the R-square value cannot be directly interpreted as the prediction power as taking exponentials to retransform the function might produce a bias.

CHAPTER 7. CONCLUSIONS

This dissertation is a compilation of five research projects investigating the emerging dynamics of sustainable transitions in energy and water systems. For every research project, I employ a Multi-Level Perspective, a heuristic developed from the sociotechnical transition literature to diagram the relationship between three primary levels of any transition - the niche, the regime, and the sociotechnical landscape. While each research project is distinct, in collection this work offers three important contributions to the literature.

First, the dynamics of intermediary actors and niche level actors working at the local level hold far more relevance to the pathways taken in a sustainable transition than the MLP literature acknowledges. More work is needed to understand the 'how' of these actors as their agency potential has institutional implications that stretch beyond the city. When looking at Chapters 4 and 5 in concert, it is also evident that the institutions that support the development of niche actors will look different at different scales. At the local level, a combination of sustained devolution in public services coupled with strong third-sector organizational structures, allowed for the third sector intermediaries to directly intervene and guide the policy process towards a sustainable transition of the energy system. In contrast, when examining water resource management conflicts at the regional level, niche actors have failed to make any qualitative impact on the incumbent regime governance arrangement, despite having many of the institutional components present that the literature suggests will facilitate integration, collaboration, and greater democratic decision making. This may suggest that scale may play a bigger role in the development of niche innovations and policies than simply an exploratory space to analyze success of actors' strategies. Additionally, both Chapters 4 and 5 suggest that public participation may be neither a guiding value of the regime, as made evident by the continued resistance towards cooperation and inclusion of grassroots actors in the governance of the ACF, or a principle value of the third-sector intermediaries working to shape the sustainable transition of our energy sector through cities, as made evident by the disregard for public participation from both the City and the intermediaries in the pursuit of passing energy efficiency policies.

Second, in recognition of the importance of scale, the transition literature must give greater attention to 'figuring out' how innovations diffuse in cities, what are the institutional implications of diffusion, and what institutional arrangements may need to shift in order to collectively transition the country from the bottom up. While in theory, every locality could employ a wide range of trial-and-error policies and shape the institutional contours of sustainable transitions to fit the specific social, economic, political, and environmental attributes, at some point there are nationally rooted institutions and policies, which underscore both energy and water systems which must be addressed. My work in Chapters 2 and 3 illustrate how even strong user preferences, supportive niche policies, and favorable economic landscapes can be insufficient to facilitate a regime change without qualitative changes to the regulatory models that guide our electricity use and the utility business models they support. In order for researchers and decision-makers to understand the true challenges of transition and separate legitimate concerns from regime argumentation, more analysis and thoughtful articulation of the policy process is necessary.

Third, as evident in Chapters 2 and 3 and 6, for those parties concerned over the pace of transition, it is critical we examine the policies and technologies framed as solutions towards a sustainable state, more holistically. While the majority of this dissertation examined the dynamics of sustainable transitions in the energy and water system as functionally different constructs, in reality these two regimes are deeply interwoven throughout the sociotechnical landscape. Attempting to develop technological and policy solutions in silo will not only slow the pace of transition but could have the unintended consequence of entrenching the incumbent industrial and technological regime constructs. Such a paradigm shift will require a much deeper and fuller understanding of the technological and behavioral dynamics of both the incumbent regime and the niche innovations, so as to shift the purpose of niche innovations to produce cross-system change.

Of course, in order to do this the analytics necessary to start assessing niche innovation as cross-system solution needs to evolve. As we see in the research conducted in Chapter 6, taking a water-energy-climate nexus approach to technological evaluation revealed that while RWH has consistently been framed as a tool for water resource management, DGPV holds promise as a tool for meeting urban water resource management challenges and comparatively produces far greater savings in terms of emission reductions and expenditures. While this is only one case study, it does suggest that reframing DGPV as a cross-system solution may facilitate greater adoption in areas where political concerns over a sustainable water system may outweigh concerns over transitioning the energy system. When combining the work done in Chapters 2, 3, and 6, this dissertation speaks to the need for rigorous analytical work and the expansion of the definition of ‘value’ for these niche technologies, as well as the institutions and regulations which dictate how value is determined.

Finally, this body of work made a number of methodological contributions. First, Chapters 2, 3, and 6 provide new methods and models for valuing the benefits of distributed resources, namely DGPV and RWH. Second, every chapter advances the use of the MLP in studying sustainable transitions. Chapters 4 and 6 contribute to the much-needed research on sustainable transitions in cities. These chapters develop a stronger understanding on the role that cities play in sustainable transitions, locally and nationally, as well as the barriers to niche development and the strategies employed by supporting actors and their institutional implications. Additionally, Chapters 4 and 5 contribute to the growing field of research examining the role of public participation in sustainable transitions. Finally, Chapter 5, albeit stalled due to political sensitivities, advances the use of the MLP framework from one that characterizes innovations as technological and policies as supporting, to characterizing governance arrangements as innovations with actors and technologies as supporting roles. While such a characterization may not be appropriate at every scale, it is evident from my work in Chapter 2 that more innovative work needs to be done at the policy and regulatory level to facilitate transition. If there is one lesson to be learned from this research it is that the technologies to transition our energy and water systems are viable, but the regulatory structures and legal frameworks which shape our markets and user behaviors are still very much path dependent.